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The ACM Magazine for Students
WINTER 2012  VOL.19 • NO.2

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XRDS: Crossroads

Volume 19 Issue 2

February 2012

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DAY IN THE LAB

ACM Foundation for Computing Machinery
Are You a Good Match for XRDS?

Happy application season! Whether you’re applying to Ph.D. programs, postdocs, or faculty positions, this is probably a very busy (and nerve-racking) time for you. Even if you’re not currently “on the market” yourself, in the upcoming months you may find yourself taking part in your school or institution’s applicant screening process. Such a process typically involves several rounds of careful review and discussion, ultimately culminating in the decision of who to accept and, in the less fortunate case, who to reject.

Beyond personal stories of triumph or disappointment, what goes on during hiring season is basically a large scale matching problem—think of a bipartite graph, with applicants on one side and institutions with open positions on the other, and the goal of matching applicants to positions according to mutual preferences of both sides. The standard computer science approach would be to feed the graph and preferences into an algorithm and get a good match as its output. In practice, however, the match is “computed” in a distributed way, through the individual decisions of the candidates and hiring institutions. With so much at stake for those involved, as well as potentially complex preferences, one can’t help wondering about the nature and quality of the final outcome.

Recent Nobel laureate Al Roth has dedicated his career to wondering about such issues. Applying the beautiful mathematical theory of stable matchings developed by Lloyd Shapley (with whom he shares the prize) and David Gale (who passed away in 2008), he studied the design of job markets and school choice programs. It turns out that in many cases, “designing the market” by establishing rules and procedures that guide and coordinate individually-formed matches can be very beneficial. Consider, for example, what would happen if the Council of Graduate Schools wouldn’t have set April 15 as “national signing day”; accepted graduate students may have had to face pressure to notify accepting schools immediately of their decision, or risk losing their spot. In some cases, a centralized matching algorithm is actually used, most notably in placing medical students into residencies.

Professor Roth has recently moved to Stanford University and is teaching a graduate course on market design. One thing he repeatedly tells his students is that if you want to convince decision makers to adopt your ideas, you have to find a way to effectively communicate the theory to non-experts. This ability is also crucial when applying to grad school or seeking a position. Being able to clearly and concisely explain what you work on and why you’re passionate about it makes a huge difference—whether you’re giving a short elevator pitch, an informal whiteboard presentation, or a job talk or interview.

This ability is one of the things we look for when inviting authors to contribute to XRDS. Even though XRDS issues are organized around a central topic or theme, and articles are written by experts in that particular field, our goal is for readers from all areas of computer science to enjoy and benefit from them. Writers are thus faced with the challenge of capturing the essence of their research and communicating the most interesting and deep ideas behind it, without assuming prior knowledge or obscuring it by too many technical details. This skill is an acquired tool, and is sometimes what separates a good researcher/practitioner from an exceptional one. Want to work on honing your skill, or maybe even try your hand at it for the first time? Please consider submitting an article about your research to XRDS. Stay tuned for next year’s themes, which will be announced in the upcoming Spring issue!

—Peter Kinnaird and Inbal Talgam-Cohen
AROUND THE WEB

On: “Unbreakable Cryptography in 5 Minutes,” by Wolfgang Richter, August 2012

What a super blog! too much info and a very short life hehehehe keep it up, good work
— udean, XRDS Blog comment

#NowReading: How to be an “Entrepredemic” from XRDS is the ACM’s magazine for students. Interesting stuff
— Ayman, Twitter, (@B_Ayman)

Measuring the Occurrence of Security-Related Bugs through Software Evolution flipbd.it/A4KP4
— Antonis Lilis, Software developer, Twitter, (@aNTwNHs)

A #college students’ guide on gaining data scientist #skills, http://bit.ly/RejiUSR #IBMbigdata #analytics
— Anjul Bhambhri, Vice President of IBM Big Data, Twitter, (@AnjulBhambhri)

More on temporal behavior, but for those interested in crowdsourcing http://bit.ly/gSbITQ #ismir2012
— Julián Urbano, Ph.D. student, University Carlos III of Madrid, Twitter, (@julian_urbano)

Now live from Cambridge Big Data event #serviceweek2012 #XRDS_ACM
— Vaggelis Giannikas, Ph.D. candidate, University of Cambridge, Twitter, (@VGiannikas)

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One of the most exciting and challenging applications of computer science and engineering lies in fostering international development. This area of work, known as ICT for development (ICTD), aims to use technology to address some of the most pressing global challenges faced by humanity, including provision of healthcare, education, finance, and agriculture in developing contexts.

Yet ICTD offers numerous challenges for computer scientists. Solutions for the developing world need to be elegant and robust, but must also account for technical constraints like slow network speeds, storage issues, or a lack of relevant and local content. Moreover, ICTD solutions are not purely technological; designers have to grapple with many foundational questions concerning the functional and technological literacy of target users—what their income levels are, which organization will operate and maintain a system, and so on.

This issue of XRDS focuses on the unique challenges and opportunities within ICTD. To this end, we have collected a range of interviews and articles from authors in academia and research labs from around the globe.

Our first two articles discuss healthcare. Atanu Garai describes how mobile technologies can be used to provide healthcare delivery for developing populations. Suranga Kasthuriratne, a software developer, details his experiences with geographically distributed collaboration during the design of a module for OpenMRS, an open-source platform that supports the administration of medical records in developing countries.

Turning to education, Arjumand Younos draws on her own experiences in Pakistan to reflect on the potential benefits of free online education for students in developing countries. Sheena Lewis then expands the scope of ICTD to address crime prevention in low-income neighborhoods of Chicago, noting that residents are more concerned about their children’s safety than health and poverty.

Sumitra Nair relates her experiences accompanying ICTD developers during field visits and describes how developers occupy the position of problem solvers while being deeply entangled within their own fields and people.

In the first, we visit the thriving ICTD group at U.C. Berkeley and talk to Kentaro Toyama, Tapan Parikh, and Jenna Burrell. In the second, Astrid Twenebowa-Larssen, Joyojeet Pal, and Ed Cutrell provide insights on doing ICTD work and offer advice for computer science students interested in the area.

Reflecting on the critical issues of culture and power in ICTD, Samantha Merritt provides further encouragement—and cautions—for students interested in ICTD projects.

Our final articles come from authors in Africa. Kathleen Diga describes how the collective efforts of the African ICTD community have led to the creation of a strong network of researchers. Finally, Mark Kamau, Angela Crandall, and Kagonya Awori describe how a new lab at the iHub in Nairobi, Kenya will improve user experience practices within their local technology community.

As researchers working in ICTD, the topics discussed in this issue are extremely close to our hearts. The power of technology could change the lives of millions of people around the world, and we hope this issue will inspire you to build technology that will improve the lives of people in developing areas around the world.

Thank you to Ryan Kelly for all his help with this issue.

—Shikoh Gitau and Nithya Sambastivan, Issue Editors
The maximum cost of an ICT innovation to be considered a necessity rather than a luxury good in Latin America.

**Blogging: 5 tips for your success**

In our previous issue (Big Data, Fall 2012) we announced the recently launched XRDS blog for students interested in computer science. We have gathered some useful pieces of advice that can help you build a successful blog or who knows, be the next student blogger for XRDS? Even if you are have blogging experience you might find some of these tips interesting, so keep reading.

1. **Benchmarking.** The truth is there are lots of great blogs out there. You already know many of them; you visit daily or weekly to learn about computing, news, or gossip. Well, apart from their informative nature, these blogs are also a great source of ideas for your work. So get out there, find them, read them, and try to understand the bits and pieces that made you begin reading them in the first place. Even very large companies learn from their competitors' best practices, so why shouldn't you?

2. **Design does matter.** Unfortunately, most computer scientists believe the thing that matters most is content. If the content is there, then people will come, read it, and get excited about your blog. Well, you know that's really not true, right? The way you present your work/thoughts/interests can affect to a very significant level the number of people who read and enjoy. Keep your blog simple and clean, make the topic of each article clear, and use CSS tools. These are just some of the suggestions you may want to follow. The Web is full of other tips. Google it.

3. **Guest blogging.** Once the content of your blog is ready, it's time to let the world know it's there. Although emails, tweets, and Facebook messages can do a great job, the blogger community is actually the most powerful one and will bring you more visitors in the long run. The idea is that in order to make them visit your blog, you should first show them that you are visiting theirs and you are interested in their work. So before you close the window, click on that small “reply” button and spend some time writing a comment that will catch their attention.

4. **Email lists.** Visitors are fantastic, but subscribers are even better! Opening a new email is much faster than searching for a specific blog in a bookmarks list. Give your readers the opportunity to receive such emails. Adding a subscription option in an easily accessible place on your blog will be enough. In the end, you are not trying to sell anything.

5. **Enjoy it!** Your blog is not a job. It is not something you have to do or something you do for living. So no matter what other people might say about it, always remember to have fun.

—Vaggelis Giannikas

**ACM Student Volunteers**

As many readers know, ACM runs many conferences. What you may not know is these conferences heavily rely on student volunteers, who help the conference run smoothly.

Typical tasks can involve stuffing bags for attendees, setting up rooms, fixing AV equipment, registering attendees, and generally running any necessary errand. Expectations of hours and tasks vary.

Student volunteers typically receive free conference registration, are fed, and may be lucky enough to receive preferential housing or travel grants. Some conferences (such as CHI) also have large parties. Unfortunately it’s not as straightforward as simply volunteering. There are normally far more people than there are openings; as such, many conferences hold lotteries. Applications close early, so keep your eyes open. Additionally, some conferences request student volunteer nominations. Once you’ve found a conference you want to volunteer at, ask around your faculty to see if any staff are attending and need some help.

For a complete list of ACM conferences, visit http://www.acm.org/conferences.

—Daniel Gooch
The organizers and winners of the Artificial Intelligence Contest for Freshmen, hosted by the University of Tehran student chapter earlier this year.
The World Summit on the Information Society has identified these eight sectors for ICT development.

**NEWS**

Harvard Undergraduates Earn Silver Medal in ACM-ICPC

The 2012 ACM International Collegiate Programming Contest (ICPC) was held earlier this year in Warsaw, Poland. This arduous contest involves a five-hour problem-solving spree consisting of eight or more complex, real-world problems. The goal of the contest is to solve the most problems in the least amount of time. Each team consists of three students from one university, who cluster around a single computer to formulate their plan of action for the cumulative problem set, design their code based on the problem statements, and build the software system that will solve the problem under intense requirements from the expert judges. Careful attention is needed from each student and team as any solution submitted incorrectly is assessed as a time penalty.

This year’s ICPC involved participation of more than 2,200 universities from 85 countries on six continents. However, earning the chance to participate in the World Finals of the ICPC involves a few steps along the way. Local contests are held within universities looking to participate and produce their best collaborative team, with this year’s participation measuring more than 300,000 students. The next phase is regional contests where students are pitted against each other in a larger scale to compete for a chance to attend the World Finals. The World Finals were held in Warsaw and consisted of 112 teams that competed for awards, prizes, and bragging rights.

A group of undergraduates from Harvard University, Spencer Liang ’12, Alex Zhai ’12 and Neal Wu ’14, impressively solved seven out of 12 total problems, winning them a silver medal for placing first in North America and seventh internationally. The team was coached and sponsored by Dr. Robert L. Walton ’66. XRDS sat down with two members of the team, Alex Zhai and Neal Wu, to talk to them about their ICPC experience.

Michael Zuba: What interests you in computer science?

Alex Zhai: It’s a great mixture of mathematics and engineering. This allows you to think about the problems in a theoretical way, but at the end of the day you also get to see the results of your ideas. In this case, in actual working code.

Neal Wu: Personally, I think computer science is one of the ways to have the highest possible impact on society. Once you’ve built a program that works well, your work is mostly done—you can get a lot of results out of it without having to put too much effort into it in the future (other than maintenance).

MZ: At what age did you begin programming?

AZ: I started doing a little programming around middle school, but never really did anything serious until college. My background and major is in mathematics.

NW: I started writing simple calculator programs in 7th grade, age 12. I then learned Pascal in 8th grade and started doing competitive programming in 9th grade.

From left to right: Spencer Liang, Neal Wu, and Alex Zhai.
Kenyans access the M-Pesa banking service using their cell phones. Can result in a 1.3 percent increase in economic growth, according to the World Bank.

MZ: What is the most useful programming trick you know?
AZ: I don’t really have a good answer for this one. Sometimes there are concise ways to do things, such as incrementing array indices while assigning it. Usually, it’s more important to try and keep things as simple as possible.
NW: I would actually say that the most useful “trick” I’ve learned is that there are no tricks. Thinking through the problem carefully and planning out your approach are going to save you the most time in the long run.

MZ: Why did you participate in ICPC 2012?
AZ: Neal Wu recruited me to be on the team. I hadn’t done a whole lot with programming contests before, so I thought it would be interesting and fun.
NW: It is a fun event and I had an awesome team that was enjoyable to work with. Plus, visiting Poland was great!

MZ: How did you prepare for the contest?
AZ: I mainly practiced a lot of problems from various online sources. Each ICPC year’s problem set is posted online (https://icpc-qual-12.contest.scorol.se/doc) and this provides good practice on what you might expect to see or solve.
NW: I actually didn’t prepare too much as I had already spent a good deal of time in high school practicing for programming contests. Our team did meet up and practice together roughly once a month during the school year. Practices generally take around five hours, so it’s tough to find a time for everyone.

MZ: Do you think this event has helped your education and technical competencies?
AZ: Yes, it definitely has. I learned to focus a lot better when I am programming. In order to do well in the contest it’s important to keep focused and develop good bookkeeping practices. I think this is useful in larger projects too because it helps you implement faster and allows you to spend more time on designing and planning.
NW: I think so. Solving these kinds of problems has helped me apply creative problem solving to more areas of life and, moreover, developing the skills to perform really well in these competitions has shown me that excellence in anything is much more about practice and learning than people think. I was terrible when I started!

MZ: What advice do you have for students who are interested in future programming contests?
AZ: The best way to benefit from programming contests is to 1) try to spend a lot of time thinking about the algorithms rather than memorizing techniques and 2) try to write clean and readable code.
NW: It’s awesome and everyone should give it a try!

MZ: Thanks for your insider help gentlemen. What are your plans for the future?
AZ: I plan on attending Stanford University for graduate school in mathematics, but first I am going to take a year off.
NW: I am still working on that one, but I am interested in startups.

For more coverage of the contest, please check out the XRDS blog. Shawn Freeman reported live from the event. (http://xrds.acm.org/blog/2012/05/2012-icpc-world-finals/).

### Top 12 Finishers

<table>
<thead>
<tr>
<th>Place</th>
<th>Name</th>
<th>Problems Solved</th>
<th>Time (min.)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>St. Petersburg State University of IT, Mechanics and Optics</td>
<td>9</td>
<td>1170</td>
</tr>
<tr>
<td>2</td>
<td>University of Warsaw</td>
<td>9</td>
<td>1547</td>
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<tr>
<td>3</td>
<td>Moscow Institute of Physics &amp; Technology</td>
<td>8</td>
<td>1131</td>
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<tr>
<td>4</td>
<td>Shanghai Jiao Tong University</td>
<td>7</td>
<td>1161</td>
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<tr>
<td>5</td>
<td>Belarusian State University</td>
<td>7</td>
<td>1281</td>
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<tr>
<td>6</td>
<td>Zhongshan (Sun Yat-sen) University</td>
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<td>1301</td>
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<tr>
<td>7</td>
<td>Harvard University</td>
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<td>1319</td>
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<td>8</td>
<td>The Chinese University of Hong Kong</td>
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<td>1469</td>
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<td>University of Waterloo</td>
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<td>Moscow State University</td>
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<td>University of Tokyo</td>
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<td>830</td>
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<tr>
<td>12</td>
<td>Belarus State University of Informatics and Radioelectronics</td>
<td>6</td>
<td>979</td>
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The newly launched XRDS blog highlights a range of topics from conference overviews to privacy and security, from HCI to cryptography. Selected blog posts, edited for print, will be featured in every issue. Please visit xrds.acm.org/blog to read each post in its entirety.

Unbreakable Cryptography in 5 Minutes
By Wolfgang Richter

What if I told you unbreakable cryptography exists? What if I told you this article has content, which is illegal in certain countries, and may be under export control in the U.S.? Well, that’s precisely what I’m about to tell you. Unbreakable cryptography exists. Cryptographic technology is illegal, or heavily restricted, in certain countries, and some forms remain under export control within the vagaries of US law.

This article will teach you: (1) a bit of the history of cryptography, and (2) how to implement unbreakable cryptography on your own in 5 minutes or less.

There are three steps to consider:
1. How will you generate a key?
2. How will you encrypt a message?
3. How will you decrypt a message?

To ensure we hit the 5 minute mark, I will begin by showing you an example in Python which we will discuss for the rest of the article. First, generating a key:

```python
from os import urandom

def vernam_genkey(length):
    return bytearray(urandom(length))
```

second, encrypting a message:

```python
def vernam_encrypt(plaintext, key):
    for i in xrange(len(plaintext))
        return bytearray([ plaintext[i] ^ key[i]]
```

finally, decrypting a message:

```python
def vernam_decrypt(ciphertext, key):
    for i in xrange(len(ciphertext))
```

The Python code listed above implements a Vernam Cipher. Coupled with the Mauborgne Constraint—you may never reuse a key, it must be the same size as the plaintext, and it must be from a true random bit source—you have unbreakable cryptography. Vernam was granted a patent in 1919 for this idea, and the US NSA considers this patent, “...one of the most important in the history of cryptography.”

**VERNAM XOR STREAM CIPHER**

Well, that was quite a mouthful. Don’t give up, we’ll go through things one at a time until you have a good understanding of what’s going on! The good news: although provably unbreakable, meaning it has been shown and can be shown through rigorous mathematical proof that no information from the original message may be gleaned from the encrypted form, the algorithm I am presenting is incredibly simple and easy to understand.

The entire technique hinges on the logical XOR function and its symmetry. XOR is a logical function, which is equivalent to true precisely when the number of true inputs is an odd number.

Here is a truth table showing XOR’s value when provided two inputs (B1 and B2):

<table>
<thead>
<tr>
<th>B1</th>
<th>B2</th>
<th>XOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Here we assume two possible bits of input—B1 and B2. We then show the XOR result for all combinations of true (1) and false (0).

I claimed XOR is symmetric, because if you XOR an original bit sequence with a second bit sequence twice, you will get the original again. Here is an example, as another truth table:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>XOR1</th>
<th>B</th>
<th>XOR2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: When we XOR A—which our ‘original message’—with B—which our ‘key’—and we XOR the result—our ‘encrypted message’—with the B—‘key’—again, we are left with A—the ‘original message.’

It is because of this property that XOR works as an encryption and decryption function—there is nothing else to it. Once you choose a key, you simply XOR the message you
want to encrypt and that gives you the encrypted form. On
the other end, when you want to decrypt, you simply XOR
the encrypted form with the key again and you will be left
with the original message.

**ENCRYPTION: EXPLAINED**
Let’s revisit the Python code and make sure we’re all on the
same page. First, the encryption method:

```python
1 from os import urandom
2 def vernam_encrypt(plaintext, key):
3     return bytearray(
4         [ plaintext[i] ^ key[i]
5            for i in xrange(len(plaintext))
6        )
```

Okay, so this Python code takes in two arguments:

1. **plaintext** — this is the original message (assumed to
be of type `bytearray`)
2. **key** — this is the key to use for encrypting (assumed to
be of type `bytearray`)

and it returns something called a `bytearray`. `bytearray`
's in Python are what you think they are, just an array of raw
bytes with no further interpretation. By operating on byte-
array’s we maintain the highest level of abstraction and
can encrypt or decrypt any message with any content.

The `bytearray` it returns is constructed by iterating over
the elements within the plaintext, and using the XOR operator
to XOR each byte bit-by-bit; thus, 8 XOR’s are accomplished
per byte. We iterate through elements by using an
index variable `i`, which goes from 0 to the length of plain-
text via the `xrange` Python built-in function.

**DECRYPTION: EXPLAINED**
I stated earlier that XOR is symmetric; thus, encryption and
decryption are fundamentally the same function:

```python
1 def vernam_encrypt(ciphertext, key):
2     return bytearray(
3         [ ciphertext[i] ^ key[i]
4            for i in xrange(len(ciphertext))
5        )
```

we’ve only changed the name of an input here from plaintext
to ciphertext, but everything remains the same as before.

**KEY GENERATION: EXPLAINED**
We still need to generate a key and for that we need a
source of randomness. Because finding sources of random-
ness is hard, we turn to a Python library function to generate
random bytes for us. In this case, we use the `urandom`
function from the `os` library distributed with Python:

```python
1 from os import urandom
2 def vernam_genkey(length):
3     return bytearray(urandom(length))
```

Our key generation function takes in one argument:

1. **length** — the length, in bytes, of the key to be generated

**WHAT’S LEFT? MILLENNIA OF CRYPTOGRAPHIC FRUSTRATION!**
Simple right? Well, mostly. If you’re thinking ahead, you
might wonder how will we distribute these keys? You’ve
inadvertently stumbled upon a problem that has bothered
cryptographers for millenia.

The nasty business with cryptography is how to securely
share a secret such as a key without having a secure channel
in the first place. It’s a manifestation of a chicken-and-egg or
watch-22 problem: to create a secure channel, we must first
have a secure channel. For millenia, this remained a central
problem in cryptography. Until Diffie-Hellman-Merkle (often
cited as just Diffie-Hellman) published a secure key exchange
method using mathematical tricks, which nullified the need
for a secure channel to exchange a secret key, the best way
to exchange keys was physically in person. Their method
is thought to have been the earliest, but secret government
organizations may have invented this technology before
them. I’d love to go through Diffie-Hellman-Merkle as one of
the simplest, yet secure, key exchange algorithms, but that is
a discussion best left for a future article to tackle.

Let me know if you’d like Diffie-Hellman-Merkle explained!

**ERRATA:**
1. Fixed first table XOR values were incorrect
   (B1=1,B2=1,XOR=1 -> B1=1,B2=1,XOR=0). Thanks to Kenton
   Murray for pointing this out.

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Carnegie Mellon University. His research focus is in distributed systems and he works
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leading to introspecting clouds. tl;dr: Cloud Computing Researcher
Fatal Injection: The Server’s Side.

By Dimitris Mitropoulos

In my first blog post, I discussed software security and mentioned some common traps such as input validation. For example, a developer assumes the user will enter only numeric characters as input, or that the input will never exceed a certain length. Such assumptions can lead to processing invalid data that an attacker can introduce into a program and cause it to execute malicious code. This class of exploits is known as code injection attacks and it is currently topping the lists of the various security bulletin providers. Code injection attacks can occur in different layers and they span a wide range of security and privacy issues.

The set of code injection attacks that involves the insertion of binary code in a target application to alter its execution flow and execute inserted compiled code can be described as binary code injection attacks. This category includes the infamous buffer-overflow attacks. Such attacks are possible when the bounds of memory areas are not checked, and access beyond these bounds is possible by the program. Consider the following code segment:

```c
#include <string.h>
void vulnerable_method (char *foo)
{
    char tmp[12];
    strcpy(tmp, foo);
}
int main (int argc, char **argv)
{
    vulnerable_method(argv[1]);
    
}
```

This code takes an argument and copies it to the tmp variable. But what happens when an argument is larger than 11 characters? By taking advantage of this, malicious users can inject additional data overwriting the existing data of adjacent memory. From there they can take control over a program or even take control of the entire host machine. C and C++ are vulnerable to this kind of attacks since typical implementations lack a protection scheme against overwriting data in any part of the memory. In comparison, Java guards against such attacks by preventing access beyond array bounds, throwing a runtime exception. To combat a buffer-overflow attack in the above case you could use strncpy instead (strlcpy is even better if you are running on BSD or Solaris) since it requires putting a length as a parameter.

Code injection also includes the use of source code, either of Domain-Specific Languages (DSLs) or Dynamic Languages. DSL languages like SQL and XML play a significant role in the development of applications. Many applications have interfaces where a user enters input to interact with the underlying relational database management system of the application. This input can become part of an SQL statement and executed on the target RDBMS. A code injection attack that exploits the vulnerabilities of these interfaces is called an SQL injection attack. One of the most common forms of such an exploit involves taking advantage of incorrectly filtered quotation characters. Take for instance, a login page. The following Java code illustrates the defect by accepting user input without performing any input validation:

```java
Connection conn = DriverManager.getConnection(a_url, "a_username", "a_password");
String sql = "select * from user where username='" + uname +"' and password='" + pass + ";";
stmt = conn.createStatement();
rs = stmt.executeQuery(sql);
if (rs.next()) {
    loggedIn = true;
    out.println("Logged in");
} else {
    out.println("Credentials not recognized");
}
```

By using the string anything’ OR ‘x’=’x as a username, a malicious user could log in to the site without supplying a password, since the ‘OR’ expression is always true. To avoid a situation like the above, you could use Java’s prepared statements. The query is precompiled on the driver that is used to connect the application with the database. From there, the parameters are sent to the driver as literal values and not as executable portions of SQL; hence no SQL can be injected using a parameter. Contrary to binary code injection, a DSL-driven injection attack is independent of the language that was used to create the application. So the problem above could similarly occur in PHP, C++, etc.

Dimitris Mitropoulos is a Ph.D candidate at the Athens University of Economics and Business. His research interests include information security and software engineering.
Seven Factors for Designing Successful mHealth Projects

Although mobile technology has the power to vastly improve healthcare delivery in developing regions, many issues can affect the success of mHealth systems.

By Atanu Garai
DOI: 10.1145/2382856.2382865

The use of mobile technology for communicating information about medicine and public health is known as mHealth. Developed countries have been using mobile telephones, miniature laptops, and diagnostic devices in the health sector for many years. With the rapid proliferation of mobile telephony in developing countries, health managers quickly recognized the potential for mHealth to strengthen their healthcare delivery systems. In fact, mHealth has created a unique opportunity to strengthen healthcare administration, care delivery, and communication among providers and beneficiaries throughout the entire healthcare system.

Yet despite the promise of mHealth tools for development, there are many issues that hamper the provision of mHealth systems in developing contexts. For example, resource constraints typically mean that installation of computer components, power backups, and broadband connections can be problematic, and providing training to health providers in using such devices can be expensive. Moreover, the absence of reliable computing infrastructure in many rural areas further compounds the issue, especially as more and more health workers begin to use mHealth for healthcare provision in these communities.

Despite these problems, mHealth systems can have many benefits and can be considered a standout among ICT for development. In health administration, the management of health systems relies upon timely and accurate data on care delivery, alongside proper management of financial, human, and material resources. However, the collection of accurate data can often be problematic, although mobile systems can sometimes help to overcome this. For example, one evaluation study in a pilot project for nutritional surveillance reported a discard rate of 14 percent for paper-based reports because of issues like illegible handwriting, missing decimals, or outliers in the forms. Yet, when forms were submitted via SMS, error rate dropped to just three percent [1]. A number of projects have used SMS in various aspects of program management: ChildCount in Kenya to enroll beneficiaries [2], Integrated Nutrition and Food Security Surveillance in Malawi to monitor nutrition programs [3], TRACnet in Rwanda to manage care for HIV/AIDS patients [4], and BloodBank SMS in Kenya to report the status of blood stocks for transfusions [5].

mHealth has also proven effective in motivating the practice of certain healthy behaviors. In 2011, Catholic Relief Services, an international non-profit organization, collaborated with mHealth technology provider Dimagi to implement the ReMIND (Reducing Maternal and Newborn Deaths) Pilot Project. The ReMIND project uses a mobile-based educational and counseling tool for community health workers serving around 1,000 people in villages in the Kaushambi District of Uttar Pradesh, India. The tool includes a mobile
phone-based pregnancy checklist with audio and visual prompts that help workers systematically counsel and assess pregnant women during regular home visits. The experiment with 10 healthcare workers suggests mobile multimedia content is helpful for managing tasks and providing information to beneficiaries. Other projects demonstrated the viability of mobile video in counseling, including mSakhi, organized by IntraHealth International in Uttar Pradesh, India, and ASHA Assist, a project in Odisha, India, organized by the University of California-Berkeley. Since multimedia appears to be more impactful than textual or graphical information alone [6], pre-recorded mobile videos displayed on the mobile phones of health workers have the potential to impart knowledge on natal issues among pregnant women in these contexts.

As more and more mHealth projects are implemented across the globe, they offer us strategic lessons and insights that can help us define factors that enable mHealth projects to achieve their objectives. Learning from these projects can help program managers, investors, healthcare workers, and the telecommunications industry at large to develop and implement projects. But what are the issues that influence the success of a particular mHealth project, and how can service providers design to accommodate these issues? Listed are seven factors that will affect the success of mHealth implementations. Of course, any list of success factors is non-static and evolving, especially since more and more projects offer unique lessons from their individual successes or failures. The list here is based on some strategic examples and highlights some salient issues that have come to the fore in past projects.

**FACTOR 1: MHEALTH IS NOT MASS MEDIA**

Many organizations are still disseminating SMS or calls in the way that television and radio broadcast their content. This process essentially entails partnering with a mobile service provider or third-party SMS gateway to disseminate SMS or calls to all the numbers registered with the mobile operator. For health campaigns, bombarding the population with SMS or calls works as advertisements and this method works best for a limited number of audiences with a high degree of interest in the advertised product. However, users of mobile phones in developing countries tend to overlook SMS from sources other than the ones from which they typically receive services. This means health information disseminated without the proper due care and attention stands to be untrusted or, worse still, ignored. A generalized message randomly distributed every so often could lack the seriousness and attention it deserves by the intended beneficiary.

One way mass messaging can work is for advertising events like local polio or HIV/AIDS camps. For example, Project Masiluleke sent some 300 million “Please call me” messages using the unstructured supplementary service data (USSD) protocol to South Africans encouraging them to undergo HIV/AIDS test. The average daily call volume to the National AIDS Helpline tripled within a few months of this campaign [7].

SMS campaigns tend to work best for promoting awareness of specific events, products, and services. Promotion through mobile communication is undertaken mostly by media agencies as part of their media campaigns. Since these campaigns are one-off, mHealth initiatives can
Tools and Frameworks

OpenMRS, Open Medical Record System  [http://openmrs.org](http://openmrs.org)
eMOCHA, electronic Mobile Open-source Comprehensive Health Application  [http://main.ccghc.net/content/emocha](http://main.ccghc.net/content/emocha)
Datadyne EPISurveyor  [www.datadyne.org/episurveyor](http://www.datadyne.org/episurveyor)
FrontlineSMS  [www.frontlinesms.com](http://www.frontlinesms.com)
RapidSMS  [www.rapidsms.org](http://www.rapidsms.org)

Useful Websites

Knowledge for Health Program  [www.k4health.org/toolkits/mhealth](http://www.k4health.org/toolkits/mhealth)
mHealth in Low-Resource Settings  [www.mhealthinfo.org](http://www.mhealthinfo.org)
MobileActive.org  [www.mobileactive.org/areaofpractice/Health](http://www.mobileactive.org/areaofpractice/Health)
mHealth Alliance  [www.mhealthalliance.org/news/publications](http://www.mhealthalliance.org/news/publications)
Health Unbound  [www.healthunbound.org/content/about](http://www.healthunbound.org/content/about)
Mobile Health Information and Resources  [www.fic.nih.gov/RESEARCHTOPICS/Pages/MobileHealth.aspx](http://www.fic.nih.gov/RESEARCHTOPICS/Pages/MobileHealth.aspx)
WHO Global Observatory for eHealth  [www.who.int/goe](http://www.who.int/goe)

seldom run for long, primarily because many such campaigns are of limited duration. In the area of maternal and child health, pregnant women will require messages on dieting, danger signs, baby growth, and other topics based on the gestational period. This means messages can be matched to target pregnant women based on menstrual cycle or their child’s gestational period. Such targeting is useful because beneficiaries may ignore healthcare messages if the system does not send the message based on the profiles of the intended recipients.

FACTOR 2: DELIVER MULTIPLE SERVICES THROUGH MHEALTH

Many health managers think of mHealth as yet another tool for data collection and communication about health behavior. They can hardly be faulted for this biased perception as many mHealth projects have concentrated only on those two aspects. However, mHealth has the potential to provide instruction and guidance to steer the patients toward attaining certain behavioral goals. In doing so, mHealth can provide guidance to access and utilize health services.

Since research suggests the impact of audio-visual communication is far greater than textual or audio communication alone [6], mHealth services using second generation, 2-G mobile telephony are likely to have a limited role in raising awareness about key health behaviors. But mobile communication can improve self-efficacy, social support, and interactions between patients and doctors, while the media itself can increase awareness and knowledge on specific health issues. Mobile communication can allow providers to tailor the delivery of information according to time, geography, desired frequency of messages, and other orientations demanded by the health and social, cultural, and behavioral patterns of the patient. As such, mHealth practices can cover more health issues, as compared to mass media. For example, mass media has been successfully exploited to raise awareness about polio in India and knowledge about polio is now very high among citizens. However, there are many other vaccines that were not covered in media campaigns, and, as a result, knowledge about those vaccinations is very low. Media campaigns and even interpersonal communication will require more resources for providing appropriate information and guidance, as compared to mobile communications.

FACTOR 3: EVOLVE BUSINESS MODELS FOR CURATIVE AND PREVENTIVE HEALTH

Program managers are increasingly looking for ways to ensure financial sustainability, both in profit-making and not-for-profit projects. While most mHealth projects do seem to be financially sustainable in the medium- to long-term, financial and other constraints mean that beneficiaries may be less likely to pay for SMS or phone calls that aim to promote healthy behaviors. This means projects targeting preventive health segments may not be able to charge their customers for services, making financial sustainability problematic.

On the other hand, beneficiaries may pay for services related to emergency and curative health issues, especially as requirement for treatment is immediate and often visiting a doctor or treatment facility can be difficult. A number of mobile operators have started providing counseling on mobile phones for a fee, which the operator deducts from the talk time balance of the caller [8]. Projects in preventive health areas like smoking cessation and maternal and child health typically depend on public healthcare budgets that are supported by taxes or other financial sources. One issue is governments in developing countries may be reluctant to support mHealth projects targeted at preventive healthcare due to contractual obligations or software-as-service models. However, governments may become convinced as more and more evidence emerges promoting the benefits of mHealth projects in areas like maternal and child health. Investors should recognize the growth potential of mHealth for preventive healthcare, before rejecting those ideas for their dependency on government contracts.

FACTOR 4: CONSIDER MOBILE DATA COLLECTION AS THE MEANS TO AN END

Until now, most mHealth projects have focused on data collection. Of course, data collection projects helped demonstrate the efficacy of mobile devices as instruments for data collection with fewer errors and lower cost. But, once the data is collected

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and stored, it does not—indeed of itself—act as a trigger for action among the intended stakeholders. There will be little change on the ground unless the data is translated into meaningful information and communicated to relevant stakeholders in a timely and acceptable manner.

Most randomized controlled trials demonstrate the change among patients who receive personalized information through SMS. However, some mHealth projects have yet to show any meaningful change because projects have failed to convert data into useful information for users. In addition to data collection, researchers have advocated the use of mHealth to evaluate performance of community health workers, make mobile payments, track supplies, and assist clinical care by nurses and doctors. To make this happen, the International Finance Corporation is currently working on a project in the Indian state of Bihar to use data reported to Mother and Child Tracking System [9]—a system to track delivery of scheduled services—as the basis for payment of compensation to rural health workers [10]. Considering that health workers sometimes wait for months to receive their compensation, they are likely to be interested in delivering services on time with the promise of regular payment.

**FACTOR 5: PARTIAL AUTOMATION DETERS MHEALTH ADOPTION IN HEALTH SYSTEM**

Donors ask for mHealth projects that work in a health issue of their choice. Examples include child vaccination and conditional cash transfer, among others. Partial automation is automating a tiny component of the service delivery—such as one polio vaccination out of five vaccines for children. Emphasis on polio vaccination is one of several services that child health programs deliver and automating data collection only for vaccination works as a lesser incentive for health workers. It is best to avoid such structural drawbacks during the program design phase.

Partial automation like this only places additional burdens on health workers by requiring they maintain records in manual and electronic formats. Such burdens can discourage them from adopting mHealth. Zambia, for example, started deploying a Health Management Information System in 1997 and initially only two modules of the system were made available to providers. A later evaluation found that the unfinished components increased pressure among health staff [11].

**FACTOR 6: MHEALTH IS INTEGRATIVE**

mHealth technologies have the capacity to integrate otherwise disparate functions or processes within the traditional health system. For example, traditional Web-based health management information systems, which collect routine service delivery data, can be used for monitoring and supervision of health workers on the ground, for evaluating their performance, and for incentivizing use. This stands in stark contrast to typical performance evaluation, which is usually considered as a domain within human resource management. Additionally, traditional media has promoted target health behaviors without any connection to providers. mHealth, on the other hand, promotes healthy behaviors with active support from providers.

**FACTOR 7: MHEALTH IS MULTIDISCIPLINARY**

Since mHealth integrates various domains within the health sector, it is multidisciplinary by nature. As a result, professionals from diverse disciplines collaborate to develop products and services. In the case of maternal and child health, for example, medical doctors can help computer programmers in defining algorithms for developing decisions based on datasets on beneficiaries. Management professionals can often shed light on the best way to process incentives for the health workers, while behavioral scientists can aid in designing messages for the providers and beneficiaries.

**TO CONCLUDE**

There is a need to have further discussion and debate on these factors to avoid common pitfalls in this new practice area. In particular, the multidisciplinary nature of mHealth has been a great challenge for many practitioners—communication professionals often do not understand the language of computer scientists, who in turn may not have total appreciation of user behaviors as they occur “in-the-wild.” On top of this, many factors contribute to the resistance of mHealth tools in the health sector and technology is not necessarily the most important factor. Appreciating the potential concerns among users and mitigating them in the design stage is the real challenge faced by practitioners of ICT for development. The good news is that students, researchers, and practitioners interested in mHealth can all play a role in enhancing healthcare for people in developing and underserved populations around the globe.

**References**


**Biography**

Atanu Garai designs systems for improving rural employment service and public food distribution in the Indian state of Odisha as part of the Odisha Modernizing Economy, Government and Administration program. He advises leading organizations across the globe on the design and implementation of ICTs in the health sector. He has a graduate degree in electronic governance from École Polytechnique Fédérale de Lausanne and is currently pursuing a master’s degree in computing. Garai is a student member of the ACM.
Designing and Developing an Open Source Medical Informatics Module

Lessons learned in planning and managing a development sprint to build a flexible, open source HL7 query service while successfully collaborating with diverse stakeholders and volunteers.

By Suranga Nath Kasthurirathne
DOI: 10.1145/2382856.2382866

Healthcare implementations in the developing world face many limitations. These include inadequate onsite resources, limited budgets, and insufficiently trained staff. These limitations affect productivity and prevent implementations from becoming self-sustainable. OpenMRS are designed, built, and managed specifically in a manner that helps address these limitations. OpenMRS follows a strict philosophy of openness, collaboration, and ownership, which directly nurtures self-sustainability.

The OpenMRS community works hard to foster volunteer groups across the globe. This has made OpenMRS one of the most successful electronic medical record (EMR) implementations worldwide, with implementations in approximately 72 countries. Recently, the Rwandan government selected OpenMRS as the national EMR system. The development of the project is a global effort as well—implementers and volunteers worldwide provide support through continual enhancement and updating.

**THE OPENMRS PLATFORM**
OpenMRS is a software platform application, which enables the design of a customized medical records system with no programming knowledge required. It is a popular platform for medical informatics efforts in developing countries. OpenMRS also features embedded support to add patients into various treatment programs (patient workflow), the creation of patient groups for data exports (cohort management), reporting tools, and proper standardization.

At the heart of OpenMRS is free and open-source code. Free and open source software (FOSS) are software products that have been liberally licensed to grant users the freedom to use, copy, study, change, and improve its design through the availability of its source code. The FOSS sector has undergone radical improvement over the past decade, rising from home-based amateur-level systems to massive and well-organized communities with proper licensing, organizational hierarchies, good management, and competitive products. The high quality of leading FOSS projects available today makes them strong competitors against rival commercial products; for many reasons, they are often considered to be preferable for ICTD applications. Primarily, FOSS costs no money to use, making it ideal for ICTD projects with low budgets and high-quality requirements. Secondly, the FOSS community encourages collaboration and participation, which goes hand-in-hand with the sustainability targeted by ICTD projects. Furthermore, investing in a FOSS project provides a variety of long-term benefits for all existing and potential implementers in the ICTD community.

**THE DESIGN SPRINT**
A development “sprint,” used in agile software development, is a period of time during which a set of specific pre-
agreed deliverables must be completed and made ready for review. The goal of development sprints, and agile software development in general, is make the software development process more efficient.

The sprint under discussion was aimed at building a module to export OpenMRS data in HL7 message format. HL7 is a messaging standard for the exchange, integration, sharing, and retrieval of electronic health information. Message data is transferred as a collection of one or more messages, each of which transmits a record or an item of health related information. It is highly prized as a means of exchanging health information with other healthcare related software such as laboratory information systems; patient administration systems; and dietary, pharmacy, or billing systems.

OpenMRS supports the conversion of HL7 messages into OpenMRS data objects. However, developers had not addressed the reverse goal of translating OpenMRS data objects into message format. Over the years, several implementations pointed out the need to support this requirement. Unfortunately, the sprint itself was not launched earlier due to other more pressing tasks.

The priority of the HL7 module sprint increased when Jembi Health Systems of South Africa required this functionality for the Rwanda Health Enterprise Architecture (RHEA) project. Jembi Health Systems is a not-for-profit NGO based in South Africa focusing on the development of eHealth and health information systems in several African countries, including South Africa, Mozambique, Rwanda, and Zimbabwe. It also maintains a research laboratory within the School of Computer Science at the University of KwaZulu-Natal (UKZN) in Durban, South Africa. Jembi's work on the RHEA initiative sought to define, develop, and implement health enterprise architecture for Rwanda. The first phase of the project was focused on building a pilot implementation health information exchange (HIE) to improve maternal health care in Rwanda.

The RHEA project design made it necessary to exchange large quantities of data between various registries and services. It was decided these data should be exchanged as standard HL7 messages. As a responsible implementer with a long history of collaborating with other open source projects, Jembi organized a meeting with OpenMRS to discuss a common approach to address the needed functionality. Unfortunately, participants at the meeting agreed that it was not viable to announce a combined sprint between Jembi and the OpenMRS core team. The reasons for this were two-fold: Jembi's requirement for this functionality was urgent, while OpenMRS's was not, and furthermore, Jembi had a very specific set of requirements for the project, while OpenMRS had yet to discuss a design plan that would be agreeable to all implementers.

It was therefore decided that Jembi should go ahead with its current development plan to build a customized module, which conformed to their requirements. Lessons learned from Jembi's effort would be channeled back into OpenMRS to help design and build a second module, which would support this same purpose, but in a more generic manner acceptable to all implementers.

As a Jembi staff member who was en-
Through community-driven open-source projects such as OpenMRS, developers, volunteers, and organizations can collaborate to improve healthcare facilities in countries across the globe.

**CHALLENGES AND OBSTACLES**
Managing a team can be an extremely sensitive process. An open-source sprint can consist of developers representing many organizations, volunteers, and students. The team could be spread across the globe; meaning development work could take place around the clock. It is therefore critical to manage outstanding development work in a productive manner. In my time as a lead on the OpenMRS HL7 module sprint, I encountered many challenges, likely to be faced in many OSS and ICTD development projects.

**Communication.** A major obstacle faced was the physical distance between developers, implementers, and stakeholders. It was important to maintain open communication between interested parties.

A series of weekly online meetings were organized to discuss an initial set of requirements and module design. They were open for all implementers and developers to discuss their ideas, although several experts in the fields of HL7 messaging were specifically invited to attend. Planning for the module took approximately one month to complete. Two more meetings were subsequently held during the development phase to discuss progress.

Design plans were also discussed on the community’s public mailing lists. There were approximately 15 separate email threads on the implementation of the module. These, as well as wiki pages created by the sprint lead, were all open for public comment. Documentation was used as a means of maintaining written records and also served as a mode of interaction for those unable to attend the online discussions.

**Managing task assignment.** OpenMRS uses the JIRA issue and bug tracker to plan and supervise sprints. The source code is hosted on the OpenMRS public github repository. The sprint lead evaluates the requirements, and converts them into a set of JIRA tickets. A developer claims a ticket, completes it, creates a pull request, and notifies the sprint lead. The sprint lead then reviews the code, and suggests potential changes or improvements. Subsequently, new tickets may also be created as the design team identifies other potential issues or improvements. This cycle continues until the lead is satisfied, after which the ticket is closed.

Developers were free to assign themselves to any of the available tickets during the sprint, but it was ultimately the sprint lead’s role to oversee progress and recommend tickets to users based on their experience, availability, and priorities.

A project lead must be aware of each team member, and of his or her role in the project. Each sprint member should be asked to take on tasks based on their abilities. For example, a full-time paid employee should be encouraged to take on critical and time sensitive issues, as they have the best chance of completing the task on time. Volunteers may also take on and complete important tickets, but it is important to take into account their level of expertise and time commitment when assigning issues.

**Encoding implementation flexibility.** While it is essential to solicit requirements from potential end users, it is also necessary to maintain a layer of abstractness so that the end product is not tied with the requirements of a specific implementation. For example, Jembi’s requirements called for very specific HL7 messaging structures and output options. However, we believed it was unwise to adopt the same structure for OpenMRS, as it would make the module less generic and difficult for other users to customize. We agreed on a more generic approach, which focuses more on building an output mechanism, while allowing end users the flexibility to decide on the structure of the messages they wished to export. The project thus focused on laying down the core level support required of the module, with customizations being left to the end users.

**Maintaining neutrality.** Several tools, such as Mirth Connect and Message Maker, already support the creation of HL7 messages from existing data. We decided against using such an interface engine, as adopting a specific tool would create a depen-
Figure 2. Percent contributions of developers by type.

We therefore set out to build our own messaging templates from scratch. After detailed study, we decided to use Groovyscript for this task, which was easy to learn and fit our requirements for extracting data.

**Project leadership as a public relations role.** The project lead is not merely responsible for ensuring the technical success of the project, but also for the overall acceptance of the module by the implementers. The project lead must take on the role of a project champion and marketer and “sell” the module to potential end users. This requires a good amount of tact, conversational skills, and project ownership. In fact, good PR skills are essential for any ICTD project, considering the need to win support from various globally diverse groups.

**THE OUTCOME OF THE OPENMRS SPRINT**

The progress of the sprint is depicted in Figure 1, with the y-axis showing the number of tickets. The sprint began with a total of 22 tickets. This number rose to 32 as additional tickets were created during the two-week sprint. At the end of the two-week period, 19 of these had been completed, reviewed, and closed, while 10 more were still under various phases of review.

Completion of the development work by type of developer is shown in Figure 2. Given this data, it may seem that collaborators/implementers played a lesser role during the actual development phase. What is not shown by this figure is that the implementers were active in other design roles not covered by tickets during this period. Implementers mostly took on administrative or supervisory roles during the sprint, as their prior work in building a similar system had given them valuable experiences on potential issues.

It is also evident that volunteers played a lesser role in comparison with other full-time developers. This was because the project required some amount of technical knowledge linked to HL7 message standards, which many volunteers lacked. Furthermore, the project was scheduled at a time when many volunteers were engaged in other volunteer work for the community.

Based on the output of the project, we classified our sprint as a success. We were able to deliver a working version of the module at the end of the allotted time period. Our team completed 90 percent of the requirements, which were agreed upon at the start of the sprint. The 10 percent of requirements that we failed to cover were low priority and do not affect the core use cases. Prior to the next release, the outstanding tickets will be resolved.

Even though we welcomed input from all implementers, we maintained a clear separation of concerns between implementers and the end product. The sprint benefited from lessons learned during Jembi’s implementation phase, but in the end, did not adopt either its design or requirements. The module also succeeded in winning support from the users, who were involved from the early planning phase.

It was essential to not only keep all potential implementers updated on the progress of the sprint but also consider their individual requirements. To meet requirements for many different groups, one must carefully identify what functionality is essential for the module and what can be left to be customized by the user. Our final design met all basic requirements, while still allowing the flexibility of customization.

**IMPROVING HEALTHCARE ACROSS THE GLOBE**

As with any FOSS or ICTD project, managing an OpenMRS sprint required a high level of skill and flexibility. It was also a massive time commitment, as collaborators in many different time zones required prompt feedback. Managing work in progress, with developers with various backgrounds and skill sets, was also a major challenge.

We anticipate the HL7 module will be implemented by many end users, and will help the interoperability between various healthcare systems. Through community-driven open-source projects such as OpenMRS, developers, volunteers, and organizations can collaborate to improve healthcare facilities in countries across the globe.

**Biography**

Suranga Nath Kasthirirathne is an undergraduate student in software engineering at the Informatics Institute of Technology, Sri Lanka. His field of interest is health informatics for the developing world. Kasthirirathne is employed by Jembi Health Systems of South Africa, an African NGO focusing on improving global health by developing information systems. He serves as a volunteer developer for OpenMRS, an open-source medical record system used across the world. He also served as a mentor for the Google Summer of Code 2012 program.

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Crime Prevention Technologies in Low-Income Communities

Using collaborative technology as a grassroots effort to reduce violent crime in Chicago.

By Sheena Lewis Erete
DOI: 10.1145/2382856.2382867

Gunshots rang loudly through the air at 9 p.m. on a Tuesday night. I had just returned from doing fieldwork in one of the most violent neighborhoods in Chicago, IL. As usual, I sat next to my window to reflect and write about my experiences and observations in a neighborhood that is more than 15 miles away from my “safe” neighborhood. It was then that I heard the gunshots and saw my neighbor running after the gunman. Concerned for her safety, I called out to her from my open window. I couldn’t even find the phone to call the police; my mind was racing. It was official. Someone had been shot not just in my neighborhood, but on my street—the place I was standing less than two minutes earlier. The reality of crime in Chicago was more real to me than ever before.

Crime has become of increasing interest to me, especially after moving to Chicago—a city with one of the highest crime rates per capita in the world. For the past two years, I’ve studied how middle to low-income communities in Chicago use technology to address crime. I attend community-police meetings, interview local residents, and perform content analysis of online communication amongst neighbors in five different areas of the city. But what does crime in Chicago have to do with ICT4D?

BACKGROUND
Violence is most prevalent in impoverished communities in Chicago. Minorities who live in low socioeconomic neighborhoods are disproportionately affected by violent crime. For example, though African Americans only make up 33 percent of the population in Chicago, they were 78 percent of murder victims in the first six months of 2012 [1]. Youth who live in these areas of the city face violence similar to that of a war zone. As a result, in 2010 state lawmakers considered bringing in the National Guard to help regulate the increase in gang-related violence [2]. In Chicago, low-income residents are more concerned about their children returning home safely from school than the other issues that plague them such as poverty, health disparities, subpar educational opportunities, and inefficient local government. Violent crime is important and relevant to ICT4D research. Although Chicago has a relatively stable government, it seems to be failing the economically disadvantaged in their human right to safety.

While seemingly powerless in changing the minds of out-of-touch policymakers, these communities have enacted methods to address local crime that is external to the police and the local government. My objective is to understand how communities varying on race, socio-economic status, and...
crime rate appropriate technology to support such grassroots efforts and if/how technology empowers citizens to take action. Though this is an ongoing study, I am finding that collaborative technology is used to support citizen action by facilitating communication amongst neighbors about crime. The type of technology used differs based on the socio-economic status of the community. In more affluent communities with less crime, neighbors use technologies that are open to a larger number of people like message boards and blogs that had loose membership restrictions. Lower socio-economic communities seem to use technologies that are easier to restrict access such as email lists and group text messaging on mobile phones. Residents in these communities cite fear of retaliation from criminals, gangs, and/or the police as reasons they do not use technology that can be accessed by a larger number of people. Residents

Though African Americans only make up 33 percent of the population in Chicago, they were 78 percent of murder victims in the first six months of 2012.
are also concerned that their feedback about crime in the neighborhood could be shared with potential offenders, and residents did not trust most technologies to truly anonymize their identity. Furthermore, the geographical definition of community seems to differ based on socio-economic status. Residents in middle class communities seem to broaden the geographical constraints of their community and where they could affect change. In lower-income communities residents are most concerned with their immediate surroundings (e.g., a radius of three blocks away from their home) and were often skeptical of their ability to enact change beyond their block.

Three themes have emerged during my study: trust, information sharing, and collective efficacy. While these themes have been noted before, the goal of this article is to encourage conversation amongst scholars and technologists about how they can be used to design effective crime prevention technologies for disadvantaged communities.

TRUST
Historically, trust between minorities and the police has been a challenge. Low-income communities that suffer with high crime rates have thought of the police as unresponsive to their needs and concerns. Some view law enforcement and other government agencies as causing more harm than good. Thus, when designing crime prevention technologies that will be used in disadvantaged communities, we should consider solutions that have little to no interaction with traditional government infrastructure but can also affect change. Accountability is one of the most important factors for these communities because they feel that their voices are not heard. How can we create technologies that have little contact with government infrastructure but also address accountability?

INFORMATION SHARING
In relation to the lack of trust, one major theme that has emerged from my work is differences in how information is shared. Many residents in disadvantaged communities tend to only share information with those whom they know personally and that live in the immediate vicinity of their homes (i.e., on their block). Furthermore, people tend to funnel information to knowledge brokers as opposed to sharing information directly with the police. Typically, knowledge brokers have lived in the community for a long period of time and have accepted the informal role as one who manages information sharing between community residents and government officials (e.g., law enforcement, alderman). Knowledge brokers are well respected amongst the entire neighborhood (e.g., residents, gang leaders, police, government officials). Effective crime prevention technology must account for the role of informal social structures such as information sharing strategies that may be unique to marginalized communities.

COLLECTIVE EFFICACY
The final theme that I pose is collective efficacy. Sampson et al. [3] said, “It is the linkage of mutual trust and the willingness to intervene for the common good that defines the neighborhood context of collective efficacy... [Collective efficacy of residents is a critical means by which urban neighborhoods inhibit the occurrence of personal violence, without regard to the demographic composition of the population.” As ICT4D researchers and practitioners, we should consider designing technology beyond the individual, but instead for the collective. While there may be a minimum amount of trust for outsiders, low-income, particularly minority, communities view collective identity as being vital to the community. Therefore, crime prevention technologies that increase feelings of agency and efficacy may impact crime and community engagement. Such technologies may remind neighbors of a collective accomplishment by exhibiting the community’s willingness to engage, which may increase reciprocity.

CONCLUSION
Crime prevention is an important topic to consider for the economic development of impoverished neighborhoods in ICT4D research. Trust, information sharing, and collective efficacy are factors that we should consider when designing crime prevention technology for low-income communities. Though gunshots in my neighborhood are uncommon, the incident was a life-changing event that illuminated what participants in my study experience on a daily basis. Safety is a human right and as researchers, it is important to protect that right by designing effective crime prevention technology for marginalized populations that disproportionally experience violent crime.

References

Biography
Sheena Lewis Erete is a Ph.D. candidate at Northwestern University. She is interested in studying and designing collaborative technologies that encourage and facilitate prosocial behavior in marginalized communities to solve social issues. Her dissertation work focuses on how middle and low-income Chicago neighborhoods use technology to address crime and how it affects offline behavior and civic participation. Erete received an M.S. in computer science from Georgia Tech, focusing on HCI, and B.S. degrees in mathematics and computer science from Spelman College.
Online Education for Developing Contexts

A personal experience with academia in Pakistan leads to using online education initiatives as an opportunity for massive improvement.

By Arjumand Younos
DOI: 10.1145/2382856.2382868

It is a generally held notion that the academic culture and the styles of teaching in my part of the world are outdated and they perhaps do not challenge ambitious minds. At least this has been my experience. For the most part, higher-education circles in developing regions limit ideas to an academic document on a shelf—a much different mentality than the top research universities of the developed world. Students have always wanted to know how the ideas that they study in the classroom apply to the real-world problems around them. Now, with world-class professors offering online courses, there may be an opportunity to get many of those questions answered.

For many students in the developing world the idea of learning from Ivy League professors may seem only to be a dream. Students in developing regions are often frustrated by the limitations of learning. In my experience, these students often reach a point where they begin to question the credibility of those teaching them and begin to get disillusioned with university education. I can personally recall many of my classmates losing interest in some of their courses by the end of the semester. I believe the majority of this frustration can be attributed to classes taught in a boring and non-interactive fashion. Outdated course content plays a major role in deflating student motivation. Natural student curiosity is replaced by course credit seeking and exploratory learning is something that can only take place outside of the institute.

From day one of my journey through computer science I knew my path would not be an easy one. Throughout the four years (2003–2007) of my undergraduate degree at the University of Karachi, I mostly learned on my own. There were very few occasions when the classroom experience was enjoyable. My learning path was mainly comprised of reading the course textbook on my own. At times that was not enough and some concepts needed more explanation from a knowledgeable teacher or perhaps a practical exercise. Back then extra help from a teacher was lacking and hence my road to self-learning was full of hardships. Today when I recall those tough times I consider them a part of a significant learning phase. Those experiences contributed to the advice that I give to young computer science students from my home country: Make the most of recent online education initiatives. This comes from my incredible experience taking two online courses last semester.

The issue of education breadth has always been a major one for most of the developing world. Even if students have access to education the quality is often in question. At a recent conference I discussed this matter with a Microsoft Researcher from India. This industry researcher voiced the same concerns as mine and was particularly concerned about the low quality of university education in our parts of the world. What we both ignored during our discussion at that point of time was the role online education could play in facilitating high-quality education. In the words of Thomas Friedman of the New York Times, “Big breakthroughs happen when what is suddenly possible meets what is desperately necessary.”

My entire academic career has been driven by a desire to give back to my own people; I am very passionate about maintaining a presence in Pakistan. More recently, my own involvement with academia in Pakistan blossomed when I petitioned to establish my own research lab within the Computer Science Department of the Institute of
Outdated course content plays a major role in deflating student motivation. Natural student curiosity is replaced by course credit seeking and exploratory learning is something that can only take place outside of the institute.

Business Administration in Karachi—an experience that could be characterized as both exciting and frustrating. I attribute my capability to establish a research lab to the standard operating procedures I learned while pursuing my master’s degree at KAIST, South Korea. The Web Science and Technology Research lab, despite still being in its infancy, has been successful. Last year it was represented at the International Conference on World Wide Web, one of the most prestigious conferences in my field.

Being a joint Ph.D. candidate at two European universities (the National University of Ireland, Galway and the University of Milano-Bicocca, Milan), it is definitely hard to spare time for a research group in Pakistan. At times it is really painful to argue for hours with people in academic circles back home on the usefulness of a research lab and why it is essential to conduct scientific research, which may come as a surprise to some in developed regions of the world where research is highly respected in the academic realm. However, in countries like Pakistan, universities focus mainly on teaching, as there is insufficient support for research. Exposure to new knowledge is a luxury, however online education can level the playing field.

Of course there are the skeptics who question the worth of online education calling it a one-size-fits-all endeavor and thus disregarding it. These skeptics cite the language barrier and lack of proper technology as possible downfalls. But I believe platforms like Coursera, EdX, and Udacity have found ways to address these concerns. Even in developing nations we now have a generation who have grown up on technologies like smartphones, Facebook, the Cloud, and tablets and this generation is increasingly comfortable learning and interacting with professors via an online medium. To further dig into the concerns raised by critics I posted a question to some university students in my social network. This sampling of students reiterated that they really want to embrace the online education revolution, disagreeing with those skeptics. A student from Burewala, Pakistan said, “I am currently a student of Virtual University and I had great debates with other students on the point of online education. When you learn, you become a better person, so there is no better feeling when you want to learn something, and its being taught in a great manner that makes you understand well. You are actually listening to the teacher, just like another student sitting in MIT or Stanford.” Another student, Faisal Hasnain, from a rural area in Pakistan, who happens to have a great interest in functional programming, took two programming courses from Coursera and was thoroughly impressed by the quality of the content. “I now understand the difference between local academia and international academia—the two are worlds apart,” he explained.

Online education as a phenomenon is not new and for years people in less developed regions have been skeptical of them, but Coursera and other MOOCs (massive open online courses) seem to be quite effective regardless of these concerns. The revolutionary ideas behind these initiatives include the concept to test, grade, and provide student-to-student help, as well as award certificates for completing courses. This new educational revolu-
training programs, launched both by government and non-government organizations, and almost all of them have failed. The new online education platforms can provide the teachers in developing countries with the opportunity to expand their knowledge for the courses they teach. The problem with education in developing regions like Pakistan, India, Bangladesh etc. is teachers who are responsible for the courses are not linked with research in the particular area and thus are not aware of current research that would advance their curriculum. Online education platforms such as the ones started by Stanford, MIT, and Harvard can help solve many problems professors of the developing world face: They can update themselves with latest trends in a particular area, which, in turn, can help them update their course curriculum. In my opinion they could even opt for a hybrid model where students and teachers both take the online class and then perform an in-class discussion of the class material.

At this critical point in time there is a lot of hype around the online education; Coursera alone is now hosting 200 courses from 33 schools with 1.3 million students from all over the world. Online courses are fast becoming the norm in Western society with an increasing number of universities opting for them. However, I see the real benefit of online education in other regions of the world as Daphne Koller who is co-founder of Coursera puts it, “It will allow people who lack access to world-class learning—because of financial, geographic or time constraints—to have an opportunity to make a better life for themselves and their families.”

In countries like Pakistan, universities focus mainly on teaching, as there is insufficient support for research. Exposure to new knowledge is a luxury, however online education can level the playing field. I believe the biggest benefit the developing world can derive from online education is for training traditional classroom professors. Countless efforts have already gone into teacher

**Biography**

Arjumand Younus is a joint Ph.D. candidate at National University of Ireland, Galway and University of Milano-Bicocca, Milan. She holds an M.S. in computer science from KAIST, South Korea and a B.S. in computer science from the University of Karachi. Her primary research interests lie in information retrieval and social media analytics. She is also a leading team member of the newly established Web Science and Technology Research lab at the Institute of Business Administration, Karachi, Pakistan.
Several leading researchers from UC Berkeley share their personal research stories, opinions about the field, and advice for students interested in ICTD.

By Nithya Sambasivan

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Kentaro Toyama, Visiting Researcher, University of California, Berkeley

NITHYA SAMBASIVAN: You have been actively shaping the trajectory of ICTD since the very beginning. How has the field evolved?

KENTARO TOYAMA: Thanks, that’s very generous, but ICTD as a field existed well before I became active in it in the early 2000s. You could trace it to the 1960s, when Wilbur Schramm asked about television’s potential for mass education, or when a computer was transported by bullock cart to the Indian Institute of Technology, Kanpur. More recently, it was in the 1980s and ‘90s when the term “ICT” came into widespread use, including in applications to international development. My role has been mainly to do some of the recent research in ICTD and to encourage the interdisciplinary academic community around it.

The field itself has evolved in three broad ways: First, it has grown in both size and visibility. In the 1990s, any discussion of PCs or the Internet in international development was largely limited to development practitioners and academics. Today, the media pays frequent attention to projects like One Laptop Per Child, and if you consider the hype around social media’s role in the Arab Spring, some of it has been front-page news. As technology penetrates throughout the world—there are now more mobile phone accounts than adults in the world—the study of ICT and development also becomes more relevant. Second, and perhaps predictably, the technology has evolved. In the 1990s, ICTD was about PCs. In the early 2000s, it was the Internet. Today, mobile phones and social media have taken center stage, and we are now on the cusp of a surge of work involving tablets. If only our understanding of ICTD evolved just as quickly as the technology!

Finally, I think there’s been some maturation, at least within ICTD as a scholarly community. Interventionists are less likely to believe a technology by itself will have dramatic impact; observers and critics are less likely to slam technology as purely dehumanizing. All of us—technologists, social scientists, critical theorists, and others—are more aware of the other voices in the field. Sometimes, I worry that we’re only becoming better at mouthing one another’s caveats, but even if it’s just more cognitive dissonance between our individual dogmas and a broader perspective, I think that’s better than staying within more insular academic communities.

NS: What are some of the challenges that ICTD faces as a research discipline and practice? How can we overcome them?
KT: I did my Ph.D in computer science, but thanks to ICTD, I’ve had a lot of interaction with people in very different fields. I once remember speaking to a social anthropologist about research topics, and attempting to explain to her the value of doing a quantitative experiment. We went back and forth, and at one point I said, “Well, if nothing else, this kind of trial demonstrates that at least for some population under certain conditions, you can expect the program will have an impact.” She responded, “That may well be true, but it’s just not interesting to me.” It hit me then that differences between disciplines are often those of intellectual temperament. Some people want to quantify things and arrive at generalized theories. Some people want to discover the colorful variety that makes each community unique. Some people want to understand and theorize about the world. Some people want to change it. And, being human, we like to believe that what we personally find most interesting to be the...
most graduate students in science and engineering, no matter how many gadgets you give them, and however wonderful the software, content, and connectivity on those devices. The one thing that would really change their situation is if they were provided with high-quality nutrition, healthcare, education, and social support—those require political, social, cultural, and economic changes first. Technology can play a role, but almost never the primary role.

My book critiques an approach to development that is technology-driven (or driven otherwise by what I call “packaged interventions”) and argues that the most important thing is to help increase “wisdom” in individuals and institutions. Ultimately, our goal in development shouldn’t be all that different from our goals for members of our own families—intrinsic growth as human beings. As for how I define “wisdom” and “intrinsic growth”—you’ll have to read the book!

Reducing the number of features that a technology has can make it more usable or more useful. The act of subtraction is as much an art and a creative process as addition.

A view of Sather Tower on the University of California, Berkeley campus.

KT: Sometime in 2008, while I was deep in ICTD research in India, it occurred to me that while technology can do some amazing things, the underlying challenges of development were ultimately human in nature. After all, the developed world is proof that the world has all of the technology it needs to be “developed.” Additional technological innovation isn’t strictly required. 99.9 percent of the poor, malnourished children of illiterate parents living in countries with minimal or ineffective governments are never going to have the same opportunities as

most important. That naturally leads to a kind of arrogance with respect to all other fields, where we say: “Those other folks aren’t doing real research, because they don’t do what I do.”

Interdisciplinarity is one of the great challenges of ICTD as a research discipline. Finding a way to transcend our disciplinary differences is critical for the field to thrive. I don’t mean that we have to eliminate our differences or come to a consensus—in fact the tension is vital. But we have to become better at understanding one another’s concerns and interests, both to grow the area of scholarship where we agree, and to expand the space of ideas where we differ. Especially where we differ, we have to find ways to judge quality work, even if it’s not work that might be “not interesting to me.”

ICTD practice has a different set of challenges, though no less severe. At the very least, everyone is united in the goal to change the world for the better. But there are still disagreements about what constitutes “better.” And real-world challenges, particularly in development, are often complex and messy. No amount of theory or knowledge substitutes for wise tenacity.

NS: Can you tell us about the new book you are working on?

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find an organization that is effective at having the kind of impact you desire [for example, one that’s reducing incidences of malaria, is helping raise rates of literacy, or is supporting communities with their own aspirations]. Spend lots of time with them to understand how they work and what constraints they face. Then, use the standards of good design and engineering to find a problem the organization is facing that could benefit from technology. Pilot it, evaluate it, and if it works well, help the organization adopt it and maintain it. Conceivably, other organizations might want it, too, but start with one organization first.

One thing that almost never works is to build a technology in the absence of a host organization, and to expect it spread virally. Even Facebook started with a core group of active users at one university, and that, too, was in a wealthy environment where everyone was well educated and had routine online access.

Additionally, for those who can let go of the need to prove their dazzling intellect and superior technical skills, one of the most effective things is to help others gain the capacity you have. Teach literacy; teach math; teach engineering; teach entrepreneurship; teach leadership. There is no end to good educational material in the world, and we don’t really even need fancier teaching aids. What’s missing is caring teachers and mentors.

It’s really essential to spend some time in the field, and for at least some members of a project team to immerse themselves in life with the group they are designing for.

Tapan Parikh, Assistant Professor, University of California Berkeley

NS: As one of the pioneers of the discipline of ICTD, how do you think the field has evolved?
TAPAN PARIKH: I am really excited to see the growing enthusiasm amongst students, academics, NGOs, development agencies, governments, and companies for the use of technology to support international development, as well as for community development in developed countries. At the same time, I think there are some inherent tensions that remain under-addressed within both the study and practice of ICTD. One tension relates to technical innovation, which pushes you toward more expensive, more complex and more resource-intensive solutions. These can often delay broader access or broader participation, which are two things that often require simpler, more accessible, or more cost-effective solutions.

Another tension is between academic and intellectual pursuits and setting an agenda that then determines how products are created and valued. By framing things at the level of an academic and intellectual discourse, it precludes participation from local users who are not on the same theoretical plain. I think we should be very cognizant to make sure that the discourse and debates happening in the field of ICTD are accessible to users and practitioners so that they too can steer the direction of the field.

NS: What are some of the current projects you are working on?
TP: Several of the projects I have worked on have officially left academia now and are more in the realm of startups and commercial efforts. One project that I worked on with former Ph.D. student Neil Patel is Awaaz De, a voice-based platform for creating and sharing information amongst farmers who are disconnected from the Internet. That’s been a rewarding project in the sense that we’ve been able to see an idea grow into a service used by thousands of people in rural India, while also creating outreach and voice for people who did not have those opportunities in the past.

Another project, Captricity, with former Ph.D. student Kuang Chen, followed a similar trajectory of spinning research into a startup. Captricity builds on a body of work that I did in graduate school on data collection in resource-constrained environments, which often have a legacy of using paper-based solutions with limited ability for digitizing the data in the field. Captricity provides an end-to-end workflow that merges the affordances and culture of in-the-field data management with the technical capabilities of the cloud infrastructure and machine learning algorithms. This combines CS research with the needs of the environment in order to improve the way we collect data in developing contexts.

I also have students working on less technical research, looking into how people are reacting to new technologies. One of my students, Neha Kumar, is looking at how the availability of Internet access and mobile devices is changing the ecosystem of music sharing, creation, and distribution. One interesting finding is that the ability to cheaply produce and store lots and lots of music is affecting the quality and appreciation of that music. Again, that is a critical perspective on the negative repercussions of technology.

Another student, Meena Natarajan, is exploring questions around privacy, information disclosure and behavior change in HIV AIDS patients. In particular, she is looking at how traditional ICTD interventions around HIV have been framed as information interventions, when one of the most important things that she is finding is that, like all of us, HIV patients care a lot about the relationships between them and their family and community. She is thinking about how ICT plays a role in not only creating new knowledge but also supporting new and existing relationships.

NS: What were some of the challenging and fulfilling moments of turning academic research into a startup/non-profit?
TP: It’s really great to show that it is...
possible to apply research given the relatively short time frame required for impact in community development. The kinds of groups we work with aren’t looking for a 10–15 year impact window. They want projects that can deliver impact on the ground almost immediately. Being able to think of new and innovative ideas that can be implemented within 2–3 years is a real challenge. We’ve been lucky to come up with several projects that had that property. It requires a continual balancing between long-term research interests and the immediate practical needs on the ground.

Showing that we can turn these research ideas into legitimate and successful business models shows we can do ICTD in very difficult contexts, see success and have technologies be adopted. It’s not all about failure—we can also succeed sometimes!

NS: Can you tell us about a few conceptual contributions ICTD has made to CS and other disciplines that it engages with?
TP: Actually I think this is something we’re still trying to do, and I think there are cultural reasons for that. One lesson that I have been continually trying to emphasize is that less can be more. In some sense, reducing the number of features that a technology has can make it more usable or more useful. The act of subtraction is as much an art and a creative process as addition. This lesson is very difficult for engineers and computer scientists because technology is always perceived to be about forward progress, which means new things and more functions, never less.

One other contribution that is already having an impact is the ability to validate technology choices in an in-situ context using field experiments. I think the scale of deployments that we work with in ICTD is very impressive for other computer scientists and should inspire other areas of computer science to engage in more longitudinal, in-situ experiments as well. I expect to see more field experiments to happen throughout computer science as a result.

Finally, I think the hardest one—and I don’t know if we have achieved this yet—is whether it is possible to create new knowledge while also serving a practical and immediate good. If you have a goal in the world, it’s OK to create knowledge around it and not just do technological advancement for its own sake. You can have technology advance for a purpose. But that’s a harder sell.

NS: What is your advice for CS students interested in ICTD?
TP: I think doing ICTD research requires new metrics for assessing yourself and your work. But if you can adopt those metrics and be comfortable within the community that also values those metrics, ICTD is incredibly rewarding work. It provides experiences that you can later use to do research in other areas as well. It is a great opportunity to learn more about the world, learn more about people, and learn about different cultures. All of those things should be relevant for technological development, and for the future of computer science. So in computer science that truly cares about the user experience and the social dynamics around the usage of computers, the sort of thing you can learn in ICTD research in new contexts, places, and cultures is invaluable in the general process of technological design and progress. Hopefully, if things go well, and if enough people assimilate those values and experiences, we can adopt a more holistic approach to technology design that embraces diverse value systems, languages, cultures, and general points of view into the design of technology. I remain hopeful about seeing that happen!

Jenna Burrell, Assistant Professor, School of Information, University of California Berkeley

NS: What is the lens that anthropology offers to ICTD?
JENNA BURRELL: I speak as a sociologist who has spent a lot of time in the anthropology literature considering groups within Africa. I employ the methodological approach most closely associated with the discipline of anthropology: ethnography. The vast archive of work in anthropology offers a sense of the huge range of ways cultures may differ, how social groups organize themselves, the variation in values and beliefs, and ideas about what is most important in life. Anthropology is, more than most disciplines, attuned to power dynamics, issues of inequality, and systems of oppression. This is important to consider when you are trying to intervene positively on behalf of people who are marginalized or disempowered, as ICTD work often attempts to do.

The contributions of an anthropological lens to ICTD are also methodological. Ethnographers are especially attentive to the relationship between researcher and research participant. Partnering with an anthropologist should give one a certain sensitivity and realism about one’s own ability to solve someone else’s problems with technology, a modesty in approach, and patience with trying to understand people who come from a very different kind of life experience.

ICTD projects generally involve researchers of a nationality and...
socio-economic background that is different from the group they are trying to build a system for. Therefore the designer or developer cannot rely on an intuitive sense of what would be useful. Anthropologists go into their field site with an openness to discovery and avoid imposing the baggage of too many assumptions. At the beginning of such an effort it is difficult to know what questions to ask. An ethnographic approach is oriented around understanding the web of relations [among people and with the existing natural and built environment] that define the context. This understanding is built piece by piece inductively, rather than by anticipating the important “variables” in advance. Such an approach helps to challenge the impulse to rely upon common sense, which so often fails when one enters a totally unfamiliar social context.

NS: You have done fieldwork in Ghana and Uganda. What are some of the methods that you employ in understanding people and technology in context?

JB: While ethnography is not a single method in and of itself, there are methods that ethnographers generally rely on. Ethnography always entails some element of participant observation. When I was studying youth culture and Internet cafes in Ghana, this meant sitting next to Internet users and watching what they do, but also observing face-to-face interaction in the Internet cafe itself. I also attended church services, youth club meetings, took public transport, went to social events like graduation ceremonies, and lived in a family home for a while. I carried out interviews, took photos, read copies of the local newspaper, and recorded radio shows. All of this was to get as rich an understanding of the social setting as possible, to understand the daily unfolding of everyday life and to experience it for myself. Sitting down to do formal, recorded interviews was also a critical component to this research. Through interviews I was able to better understand the perspective of youth, their aspirations, values, and the meaning they attached to their activities in the Internet cafe and elsewhere. It is this combination of efforts not just to observe human action but to understand the meaning underlying those actions that produces what the anthropologist Clifford Geertz calls “thick description.”

I also worked closely with a research assistant in both Ghana and Uganda. In Ghana it was Kobby Asare, a professional videographer I happened to run into at an event my first week in Ghana. He played a critical role in helping me find the Internet scammers I ended up talking to. In Uganda, it was Julius Matovu, a Ph.D. student in sociology at Makerere University. In my research in Uganda, which was carried out primarily in rural areas and looked at mobile phone use, I benefited from Julius’s introductions to people in his own field sites as well as his excellent translation work.

NS: Can you tell us about your new book, Invisible Users: Youth in the Internet Cafés of Urban Ghana?

JB: In the decades since the Internet was first commercialized, people from ever more diverse regions of the world are coming online. However, social research on this transition has been limited and my book is an effort to contribute toward better understanding the Internet’s new diversity. The book is based on my ethnographic work in Accra that began with a nine-month period from 2004 to 2005 when I lived in Accra and was in the Internet cafes and interviewing users on a daily basis. I was able to revisit Accra and the Internet cafes over a period of six years to note the changes in the Internet cafe scene and to see how some of the young Ghanaians were impacted (or not) in the longer term by their use of the Internet. I also wanted to explore the relationships with foreigners they cultivated online. The broader research question was:
How is the Internet experienced in the margins of the global economy?

I argued in the book that the “digital divide” as a way of framing problems of access is becoming increasingly less relevant. Going online raises a whole new set of challenges and problems of membership and exclusion that cannot be reduced either to simple binaries of access or to degrees of skill or literacy. In particular, I found that cross-cultural interactions online (between Ghanaians and the Europeans, Americans, and others they encountered) were often fraught and unpredictable. Online communities were not always welcoming spaces. The power dynamics online were shaped, in part, by Ghana’s marginal status in the global order, thereby motivating young Ghanaians to build connections with foreigners [as a way to get beyond this marginality]. Unfortunately, this made them subject to the limited attention and prejudices that came out in their interactions with foreigners. These interactions were often frustrating and, for some, disillusioning.

That’s the critical take of the book. It’s also about the incredible creativity and agency of these young Ghanaian Internet users. I looked at many different spaces and modes of sense-making surrounding the Internet in Accra such as through rumors and in church sermons and testimonials. In the book, I talk about the dynamic and informal youth groups that many young Ghanaians formed or were members of. I address development in one particular chapter recounting the World Summit on the Information Society, which had a regional conference in Accra during my initial fieldwork stint. However, I also argue that the baggage of using an exclusively developmentalist framing can obscure an understanding of how technologies become meaningful, useful, and desired on terms set by users. In ICTD work, rather than redefine “development” when forms of technology use fall outside of the scope of development goals, they are too often cast as forms of misuse. The populations who live in the so-called “developing world” don’t necessarily spend much time thinking about their needs in terms of development as it is understood within aid agencies.

NS: In your opinion, what are the ways in which the mobile is changing the notion of the Internet (if any)?

ICTD is incredibly rewarding work... It is a great opportunity to learn more about the world, learn more about people, and learn about different cultures.

JB: I think the shift to mobile-based Internet access may be alleviating some of the social pressures and problems of shared access settings. As much as public Internet cafes created a space for informal learning about how to use the Internet, the dynamics of these spaces could also be quite exclusionary. In my research, I found young women were much less comfortable in Internet cafes. Young women also often had particular household responsibilities that keep them from having the same kind of time to hang around in Internet cafes as young men. A mobile phone, however, can be carried along while fulfilling other responsibilities. So, for example, I’ve talked to young women working at their mother’s market stalls (selling tomatoes, or shoes, or whatever) who, in their down time between customers, find time to use the Internet on their mobile phones.

I don’t, so far, see that what is being done on mobile phone-based Internet connections is vastly different from what is being done on computers in Internet cafes, but I think more research is required on this. One problem is that bandwidth limitations in Ghana constrain users on any platform. So I’m not sure this shift is “changing the notion of the Internet” or how it may be.

NS: What is your advice for students interested in ICTD? How should they think about social and cultural factors in designing a system?

JB: In the computer science community, many people hear the word “culture” and reach for something by Geert Hofstede, but his model of culture has never been shown to have much predictive power. His dimensions of culture are particularly limited in ICTD contexts because his work is based on studies of affluent, well-educated people who are distinguished only by nationality. His model does no more than establish a very static set of characteristics that may or may not be particularly relevant to the system, device, or design an ICTD researcher is building. It treats “cultures” as internally homogenous, which is also not very helpful if you are trying to navigate and account for status dynamics (for example) within a culture something that is often necessary in ICTD work that must negotiate gender, caste system, and class differences. Hofstede’s work can give one a very false sense of understanding.

More up-to-date scholarship recognizes that culture is dynamic, that it is negotiated and flexible, that it is susceptible to many sources of influence. It is not something that becomes universally and inflexibly instilled into all individuals born into a particular society. A book to start with that I would recommend is Cross-Cultural Technology Design by Huatong Sun, but books alone won’t help you answer the question of how to design for a particular group of potential users. It’s really essential to spend some time in the field, and for at least some members of a project team to immerse themselves in life with the group they are designing for. This sort of observation will answer many questions that you did not think to ask. It’s absolutely normal to feel a sense of discomfort with the way other people live [whether their conditions might be considered impoverished or not] because this gets to deep-seated beliefs we have about what is good and right. It’s important to ask questions, and give yourself time to get past knee-jerk reactions and quick judgments. If you’ve done the work right you should come away from any community with ideas about what designs might improve some aspect of life and be well-received, but also with some level of appreciation for how people do things in that part of the world.

Biography

Nithya Sambasivan is a User Experience Researcher at Google.org. She has a Ph.D. in informatics from University of California, Irvine and a master’s in human computer interaction from Georgia Institute of Technology. She has interned at Microsoft Research India, IBM Research TJ Watson, and Nokia Research Center.

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A Social Scientist Sits Among ICTD Workers

Reflections on the place of qualitative methods in ICTD work.

By Sumitra Nair
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In a prior work life, I had the privilege of being the sole social scientist sharing workspace with a team of highly skilled software engineers and computer scientists in a high-end computer lab at one of India's best engineering schools. The team explicitly focused on building IT solutions oriented toward development problems like education, agricultural extension, and so forth. As an ethnographer, I recorded sites of ICT penetration in our city. But these IT professionals were looking to explicitly intervene in the city in particular, and the nation more ambitiously. That was my first encounter with explicit ICTD work.

It was also the first time I started asking questions about what it means to do ICTD work, particularly as computing professionals. What are their methods? How does doing ICTD work intersect with these engineers' work practices, and their vision of development, technology, and, more specifically, their target community—as problem definition and not just solution? In other words, how does this kind of engineering work intersect with their subjectivities?

Like the significant community of ICTD workers globally, these teams tended to use qualitatively informed research methods like interviews and observation to understand their “field sites.” Even within the same country, they see field sites as conceptually different and distant places that the ICTD worker had to make visible and intervene in. But what are the implications of using these methods as also tools of producing knowledge about the field in which they chose to intervene? As ICTD has emerged as an ever-growing domain with a diverse, global community of extremely skilled practitioners, I return to these questions. I frame them in the context of a small software development firm in India that is building a solution to support India's largest poverty alleviation program.

Coding for the Poor
One of my current projects is a study of a large information infrastructure being built by the government to manage India's largest poverty alleviation program, which is based on the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The program is built on a Right to Work structure, which means the State must provide at least 100 days of paid unskilled employment every year to every rural household that has adult members willing to work, at a rate not less than 100 rupees per day (about $2 USD). These typically include public projects like building roads and digging wells, which provided employment to almost 50 million households in 2011–2012 alone [1]. Considering the scope and scale of the project, and the amount of data management this requires, the central government built a massive digital information infrastructure with its own management information system (MIS), called NREGAs, as its centrepiece [2]. Simultaneously, the government invited small, domestic, private information technology companies to carry out modular innovations that could improve this system [3], which led to a series of pilots, testing, and developing by these small players. Despite no assurance of monetary or technical support from the Indian government, these enterprises went ahead either in the hope of future contracts (keep in mind that even a small contract in a project of this size could be significant), or as just a new site to push their own skills. I studied one such software-developing agency that took on the challenge of building a new NREGA-focused solution in two Indian states.

This enterprise, which we shall call Digital Enterprises, self-identified as a software solutions enterprise deeply invested in ICTD work. One of its most
successful products is a solution it built for tracking fertilizer distribution in rural India. The organization is also clear that it has profit goals within its development commitment. It undertakes corporate projects to generate “running money.” The company meets the definition of the small software solutions enterprise: It has about 30 employees, all with degrees in different field of computing; the average employee age is around 30; it has small office spaces in Delhi and Mumbai; there are design, implementation, and evaluation teams, but team membership is fluid; and almost every team member has worked on every project at some stage. Their NREGA-oriented solution included a biometric component where workers on NREGA projects could use the biometric device to register with the program, mark attendance, and even access their records, all using thumbprints. The data collected would be transmitted from the device to central servers via GPRS. In case of weak signals, the device could also hold data for retrieval later. Unlike most ICTD researchers, I did not occupy any formal role within their project. I had the privilege of purely being a researcher and recording everyday goings-on. Of course, I was most welcome to contribute to their “fieldwork” if I felt the need.

This last open offer to participate in “fieldwork” led me to inquire what they meant by the field. Where was it? Who went there? When I asked them about what prepared them to enter the development sector, I was informed that it was their sense of the “field.” By this they meant their visits to the rural hinterland for which they produced solutions. Particular team members were identified as having a special rapport with the villagers where the organization ran tests and demos. These members, also developers, who were part of the design and implementation teams, go out into villages and spend significant amounts of time (varying from a few days to months), and interview and observe people they identify as stakeholders. It is crucial, they stated, they don’t just administer a survey, or conduct “testing in office.” Instead, it was important to engage. The visit that I accompanied them on was a three-day affair to an NREGA field site in a rural district in the state of Madhya Pradesh. This was to be the fourth in a series of visits that had spanned over many months. They planned to test a partic-

The visiting test engineer occupies a complex position of mediator/problem solver/tech-evangelist between the product, the beneficiary, and the state.
ular feature on the NREGA biometric device as well as shoot a promotional video for the project. The stakeholders they had identified in this village were a couple of NREGA beneficiary families that had been recruited as test users over a period of time, as well as the village’s governing body (the elected village head and secretary, in particular).

I would like to draw attention to the presence of another key stakeholder, or political actor, in the field—the developer. He or she shapes the product in at least two critical ways: “out in the field” and also back at his or her workstation. I briefly discuss these two sites, and the developer in each site.

THE POLITICAL WORK OF CODING: OUT IN THE FIELD TO THE WORKSTATION
Wolff Michael Roth notes in his study of graphing techniques that the site for critical expertise is both in the data itself, and also the ability of the expert to build and demonstrate shared meaningful context for the user [4]. In this latter sense particularly, the visiting test engineer occupies a complex position of mediator/problem solver/tech-evangelist between the product, the beneficiary, and the state.

Both officials and NREGA beneficiaries approached the developer I accompanied with grievances about the whole spectrum of the NREGA program. He had to address delayed payments, allegations of corrupt village administration, and local political favoritism. The developer offered Digital Enterprise’s NREGA solution as an answer to these questions: The biometric device was going to make corruption very difficult; It would track payments; and thereby make local politics accountable. This communication highlights at least two aspects that computing practitioners in ICTD who are out in the field should consider: First, using tools informed by qualitative methods like those used by my participants also implies the researcher, who is also the developer, be aware of their deep entanglement with the field—in everyday village politics for instance. Integral to using qualitative techniques is the knowledge that the researcher is deliberately included within the setting or “context” [5, 6, 7, 8]. In fact, the very act of interviewing and interacting with their participants in the field, including introducing artifacts like their biometric devices and mobile based interfaces, provides a rich opportunity for them to be reflexive about their data collection activities, and their own role in creating and mediating the context. It is also the place to be aware of the political work they do when inserting artifacts into the field, or their technical expertise being seen as generalized, overarching expertise. Imagining the field as a dialog [9] provides the

The field engineer demo-tests the solution out in the field with NREGA beneficiaries.
Ethnographically inspired methodological tools do not produce objective and transparent accounts. These are necessarily partial and embody the researcher’s own concerns and subjectivities.

A researcher/developer with a mechanism to not just describe and report back, but to represent the field in more analytically useful ways during system/solution building back at the workstation.

**THE POLITICAL WORK OF CODING: AT THE WORKSTATION**

Equally critical, and less visible, is the awareness that building the solution or application back at the workstation is itself political work that does not cease when one returns from the field. Or, to restate, ICTD workers would gain from being aware of the political work of solution building. Ethnographically inspired methodological tools do not produce objective and transparent accounts. These are necessarily partial and embody the researcher’s own concerns and subjectivities—in short, personal politics [10]. Often, especially within ICTD project work, developers get deployed as instruments to identify problems and answer questions, and become a mechanism to strictly and narrowly identify end users and their needs in the service of system design [7]. But coding itself is subjective. Gary Downey, whose book title I shamelessly borrowed for this article, in his description of CAD/CAM experimentation and instruction in a university lab in late 1990s, notes moments when engineering students try to “locate” themselves in the coding exercise that produced beautiful engineering images [11]. He describes the act of coding as the transcription of human agency to the machine (by literally entering the codes). Consider the distribution of agency that is legislated through code. For instance, Digital Enterprise developers at their workstations in Delhi and Mumbai offices will legislate the relationship between NREGA beneficiaries and their right-to-work program information in remote Madhya Pradesh. These ICTD workers—the developers moving between the field and their workstation—would gain from being cognizant of the unique position of power that they embed into their solution. They are also in a unique interstitial space between the state that runs the existing large NREGA database, and what Digital Enterprises hopes to sync its own solution to, and between a beneficiary group that is far away from any meaningful access to the system at present. It has the power, however small its scale, to bridge—or, at the very least, interface—between these two critical stakeholders. And the design of Digital Enterprise’s solution would carry the weight of this interaction.

**CONCLUSION**

In closing, I would like to draw attention to the growing conversations in human computer interaction (HCI) and ICTD, on postcolonialism, colonialism and computing [12, 13, 14]. Taylor, for instance, inverts the commonsensical references of “unfamiliar communities,” far flung places “out there” [14] to reflect on what these locations mean for HCI, ICTD, and by extension, for computing. He recalls Helen Verran’s experiments with Yoruba-speaking children, where she attempts to understand their ordering practices of the physical world using mundane objects like peanuts, water, and Coke. Ultimately, she points to the critical work of her own presence, her “obsessive bothersome” in the field [15], and the practical work of doing science that all created the conditions for her to capture her findings. I stress the need to make these connections, and the need to invoke them not just across geographies and when speaking about the transnational work of ICTD, but also within geographies when considering questions of public engagement, design, and power, where skilled computing labor is deployed in the service of marginalized communities globally. The already embedded qualitative techniques provide a rich place to start.

**References**


**Biography**

Sumita Nair is a doctoral candidate in the Department of Science and Technology Studies with a focus on infrastructure studies at Virginia Polytechnic Institute and State University. Her work examines the building and maintenance of information infrastructures, especially those oriented toward publics, particularly in non-Western geographies. Nair draws on anthropological methods to study material and non-material productions within these large information systems. More generally, she is interested in the theoretical intersections of postcolonial studies and STS. In a previous life, she worked as an ethnographer with Microsoft Research India for the Technologies for Emerging Markets group, where she studied technology use, and entrepreneurial networks within the urban slums’ informal economies, mostly in and around Bombay. Nair holds an undergraduate degree in sociology (Hindu College, Delhi University), and master’s degrees in sociology (Delhi School of Economics) and science and technology studies (Virginia Tech).

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Voices in ICT for Development

Researchers from around the world tell us about their personal and institutional efforts in international development.

By Nithya Sambasivan
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Astrid Twenebowa Larssen, Ashesi University College, Ghana

NS: How does Ashesi University engage with its students? Is the model different from other government and private colleges in Ghana?

ASTRID TWEENEBOWA LARSEN: Ashesi was founded in 2002 to help develop Ghana by offering an alternative to other traditional universities in Ghana. Although several of Ghana’s presidents have studied at the traditional, the institutions are crowded and have a reputation for producing graduates who lack the practical skills necessary to productively contribute to the development of Ghana. Ashesi offers smaller classes, a lower student to professor ratio, and a discussion-based format to allow for more student engagement. We train our students in critical thinking and problem-solving skills using a project-based curriculum to allow them to practice the theory they learn. The Ashesi education is based on a liberal arts core curriculum and throughout our degrees there is a focus on ethical conduct. Corporate Ghana is reporting that they are finding our graduates and their skill sets very valuable.

Ashesi awards scholarships based on academic merit, though the concept of a scholarship is still new to most Ghanaians. We have, however, been able to reach students who otherwise would not have been able to afford a university education. Several of our top performing students and alumni have been the first in their family to go to university. Each year between 30-50 percent of our students receive partial or full scholarships.

We are passionate about our approach and what we have been able to achieve in our first 10 years. Ghana has so much potential and Ashesi is an inspiring place filled with great people working to fulfill Ashesi’s mission—to educate a new generation of ethical and entrepreneurial leaders for Africa.

NS: As a professor teaching human-computer interaction in Ghana, what are the ways in which you contextualize your teaching materials?

ATL: In the HCI course I teach I try to give the students a general overview of HCI, as it is the only HCI course in our computer science [CS] curriculum. I have tried to develop a course that has all the key components of a good user-centered design course. I think the core principles and methods of good user-centered design force a practitioner to engage deeply with whatever context they are working in and this is where the course really differs. Students are studying and designing for user groups in the Ghanaian context, but learning approaches to understanding users and their contexts that are universal.

I conceptually divide the HCI course into three main sections: First, developing understandings of people: Things like how we learn, how we remember and how we carry out tasks, as well as methods needed to extract this understanding. Then, design: What are tools and processes for good interaction design? Finally, evaluation: Understanding the methods available to us in HCI for evaluating designs, so that they can be refined and improved.

In the Ashesi curriculum, we have an explicit focus on critical thinking, ethics and leadership. This aims to instill concern for others and foster transferable skills, including those relevant for solving problems in any...
context. So when students do projects they work with real clients with real design challenges. For the semester project in our HCI course last semester, one of the projects was called “Fun together through Mobile”. The resulting design was not unlike existing social software, but it had features with unique Ghanaian flavor. One of the features I particularly liked was the ability to announce your arrival at a party using a “whisper” or “shout”. The “whisper” could be used to announce your arrival to a special someone, while the “shout” was used to announce your arrival at a party with your entourage.

Another group worked with one of our alumni companies to improve their bulk SMS messaging services. Sending bulk SMS is a common way for churches in Ghana to communicate with their members. There are several locally developed services, though they are not necessarily easy to use. One of the biggest challenges was to explain the importance of standard phone numbers so a church staff member can send SMS to a large number of people on an ongoing basis. The group ended up designing a wizard for an Excel plugin.

**NS:** How do you incorporate the subject of ICTD into your teaching?

**ATL:** The field of HCI engages computer scientists and technologists in the task of investigating the role of technology in whatever context you are operating in, and creating technology solutions suitable for use in contexts across the globe. So I keep questioning whether the D in ICTD, and in HCI4D, is really necessary. Is it necessary to separate ICTD from HCI? Isn’t good user-centered design enough to design appropriate solutions? Other than using ICTD as a term that tries to designate a field, I don’t really use the terms other than making my students aware of them. My colleague, Ayorkor Korsah, and I ran a session on the topic of “ICT with or without the D” at 2012 the ICTD conference, where we discussed these topics.

At Ashesi, we provide ICTD and HCI4D literature as part of the reading for the HCI course, but only because this is where most of the literature for our context is being published. There is not yet a lot of material on technology usage and interaction design in Africa that is not considered to be ICTD or HCI4D. It often seems that all research in technology design in Africa is automatically published in one of these fields, though I would argue this shouldn’t always be the case. In other words, just because a piece of research is done in Africa doesn’t necessarily make it ICTD.

**NS:** What are some projects you are working on?

**ATL:** One project relevant to this issue investigates everyday mobile use practices in emerging economies. I work with researchers and industry, both in and outside of Ghana, to learn about how people are using mobile technologies. I study mobile Internet use and non-use, strategies individuals and groups use for managing information and infrastructure across multiple SIM cards and phones on different networks, and the use of mobile technology in literacy building.

Together with two of my Ashesi colleagues, Kajsa Hällberg Adu and Kobby Graham, I am experimenting with different uses of social media in the courses we teach. For example, we ran a competition in a first-year writing course asking students to use Twitter to write engaging micro-stories based on news headlines around the world, primarily as a way to improve communication skills. We are also using course-specific Twitter accounts or hashtags, in some cases integrated into our courses’ Moodle pages, and we use Twitter as a way to share resources, reminders and stay in touch with our students.

If you are a designer or researcher interested in how people use, design and appropriate technology with resource constraints and ingenuity, you will find Africa a diverse and amazing place to visit.
developing a methodology for extracting the understandings we need to accomplish this. This would hardly qualify as ICTD research. Or some might argue that it is, by altering perceptions about Ghana and Sub-Saharan Africa [for the better, hopefully].

NS: What are some projects your students are working on?

ATL: As part of their final “Leadership as Service” course, all Ashesi students are required to do volunteer community service activities before graduating, and a number of student projects have been inspired by community service experiences. For example, Diana Osei, a computer science major, is working on a continuation of her final year thesis, where she looked at ways in which technology can help teach people who can hear [non-deaf] to use sign language. This project was inspired by Diana’s community service project at the Cape Coast School for the Deaf. During her time there, Diana came to realize that her communication with the students was impoverished because of her lack of sign language skills. Diana’s project was awarded a Kasahorow Fellowship grant earlier this year.

In other areas, Kezia Sampson [nee Arko], a management information systems [MIS] major, worked with children aged 5–7 in two schools in two different socio-economic areas of Accra, to develop user interfaces for basic literacy and numeracy. Her work is particularly interesting as it evaluated the applicability of principles and guidelines for Web application development for Ghanaian children. Clickonate, headed by Dennis Asamoah-Dwusu [CS major] and Alberta Boateng [MIS major], is a mobile and Web app for donation to causes by having people read a short message on their mobiles. Finally, Kobla Nomi [CS major], is developing a 3-D version of Oware, a traditional Ghanaian board game. Oware is from a family of African board games known as the Mancala games, all of which have basic count-and-capture rules of play. In the past, these games served as a method of instilling and sharpening arithmetic skills.

In each of these projects, Ashesi students or recent graduates are using their skills and efforts to affect change, change perceptions, and having impact. These projects illustrate initial efforts by young technologists. Taking these projects to the next level involves translating them into real and sustained impact for their intended communities.

NS: What is your advice for students interested in doing ICTD in Africa [both locals and visitors]?

ATL: Thorous user centered design can be applied universally. Be rigorous about learning about the communities and contexts in which your design solutions might be implemented. Africa is a large and diverse continent that is experiencing rapid economic growth. Technology is being developed and is used in innovative ways. HCI, interaction design, and UX are still not recognized in the way they are in the U.S., Europe, and parts of Asia. Businesses do not see the need for HCI; therefore, local information and funding are limited for research and commercial technology design projects.

There is not a great body of research to draw upon when it comes to HCI and interaction design research in Africa. Basic statistical information might not be complete or correct, if it can be found at all. This is both good and bad. If you do research based out of Africa there is not a lot to build on. But if you do it, it can be seminal. Overall, if you are a designer or researcher interested in how people use, design and appropriate technology with resource constraints and ingenuity, you will find Africa a diverse and amazing place to visit.

I keep questioning whether the D in ICTD, and in HCI4D, is really necessary. Is it necessary to separate ICTD from HCI? Isn’t good user-centered design enough to design appropriate solutions?

NS: Can you tell us a little bit about yourself and the work you are doing at University of Michigan?

JOYOJEE Pal: I work in the School of Information where I teach classes on technology and economic development. Classes in this space tend to be fairly multidisciplinary, and you are typically likely to read work from anthropology, management studies, computer science, or from the New Yorker. So the students likewise tend to be from a range of disciplines and backgrounds.

On research I have students who work on a various ICTD-related issues, my own work is in assistive technology for people with disabilities in low- and middle-income countries. On this I am interested both in new low-cost assistive technologies and social and policy issues relating to peoples’ adoption of assistive technologies. We have just finished a three-country study of screen reader use by people with vision impairments in India, Jordan, and Peru.

NS: You have a rather unusual background. Can you tell us more about how you got into ICTD?

JP: I got a bachelor’s degree in commerce in Mumbai, which means I am trained as an accountant. I spent a few years in India working at a newspaper and in Web design. In the process I got a contract to create a website for a politician – this was back in 1998. I was surprised at the time at how a politician used a technocratic image to project himself as progressive leader. A few years later, when I was in
the master’s program at the Information School in Berkeley, my interest was rekindled when I realized the campus had a great environment for doing ICTD work. This is not just because of the community of folks who work directly in ICTD, but more because of the rich environment of area studies, development studies, and design in Berkeley. Although I got my Ph.D. in regional planning, almost all of my research was with a group in computer science, and my internships were at Microsoft Research. So I had the benefit of being on all sides of ICTD.

**NS:** What is the experience of being a faculty in ICTD like?

**JP:** The experience of being faculty is incredibly rewarding—especially if you enjoy teaching and mentoring. As a faculty member in ICTD you have the advantage and the responsibility of working at the intersection of academia and practice. So there is a good chance your students will end up working on projects and topics that require you to advise them on real world implementations. Such projects have implications for the students as well as for the populations with which they are working—one needs to be prepared for this as a faculty member. The field has its share of driven self-starters, so we as faculty have the benefit of attracting students who come in with an idea of what they want to build or study, and often where they want to do it. But being at the intersection of engineering and social sciences, both of which proceed very differently as communities of practice, one often needs to know where to build, where to wait and study, and where to do nothing. Most importantly, if you work in ICTD you also need to be comfortable working with projects in a range of locations, including ones you have no experience with.

**NS:** What does ICTD mean to you? Why is it important?

**JP:** I see myself primarily as a teacher and an academic rather than as a development professional—so I see ICTD from that lens. I don’t necessarily belong to either camp on the issue of whether technology will save or ruin the developing world. To me, ICTD gives us a unique forum to not only study and discuss these issues, but to also play a role in ventures that will be plunged into this world. If you look at the attendance of the ICTD conference or the composition of many of the major groups in this space, you will find that this is one of the few forums where engineers, social scientists, and industry professionals work very closely together in a real functional way—this is really rare and very fulfilling intellectually and personally.

We have a fairly low tolerance for techno-utopianism; we want to see genuine evidence that a technology is both useful in vivo and reasonable from a cost perspective.

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complicated than this. While access and infrastructure are certainly important, the field of ICTD has evolved to begin looking at much more targeted domains. Research in ICTD now tends to focus on technologies that are specifically aimed at particular problems and contexts—for example medical records systems for rural health clinics or usable mobile money applications used by low-literate people.

A second major change is that ICTD research is now much more conscious of implementation and rigorous evaluation in the field with real users. A project intended to be used in rural Ghana or a slum in urban India will not be taken seriously unless there is evidence that it will actually work in the context it’s intended for. This is one area where TEM has been very successful and is one of the main things that attracted me to the group. Researchers in TEM are inclined to realistic and pragmatic interventions and studies, and we have a fairly low tolerance for techno-utopianism; we want to see genuine evidence that a technology is both useful in vivo and reasonable from a cost perspective.

**NS: Can you tell us about some current projects at TEM?**

**EC:** One of our major research interests lies in understanding how computing can help to improve global health, and especially how mobile phones can be used to that end. We have several projects in this area. For example, in collaboration with Dimagi and Real Medicine Foundation [RMF], we conducted a study of a deployment of a mobile phone-based system for tracking child malnutrition in rural India [1].

In other areas, we are exploring how computing may be used to improve education in resource-constrained areas. One interesting project in this domain is a means to support in-class polling [similar to “clicker” technologies] at a very low price. When used with appropriate pedagogy, clickers have been shown to improve teaching outcomes. However, clicker systems can be very expensive—typically $30 USD per device, plus a receiver base station and the supporting computer. By using a standard webcam and laptop [or smartphone] together with simple codes printed on normal paper, we are able to quickly and effectively mirror the functionality of clickers [2].

One of the major challenges in ICTD work is that reliable and rigorous evaluation can be much more difficult than in other domains. Last summer we did a study showing just how difficult this can be by demonstrating that if researchers aren’t careful they can easily get grossly biased responses. We showed that we could get people to say that they prefer obviously inferior technology simply by suggesting that it was authored by the interviewer. Indeed, this is important for anyone doing research in which you ask people to evaluate technology.

**NS: ICTD lies at the intersection of several disciplines. In your opinion, how does ICTD embrace inter-disciplinarity?**

**EC:** Interdisciplinary work in ICTD is critical for success, but it’s very hard. ICTD research depends on the tools, methods and understanding brought by all these different areas. I think that most ICTD researchers recognize the importance of working with people from other fields, and most genuinely want to reach out and understand the work of these other areas, but it can be very challenging. Perhaps the biggest obstacle is what I like to call “epistemological impedance mismatch.” The problem is that these different disciplines may have very different epistemologies: Ideas of what counts as “evidence” or “truth” in anthropology or policy may be very different from those in engineering or global health. The challenge for all these folks is agreeing on common frameworks of communication and understanding. This is very hard, but the potential benefit of synergy can be huge. It’s also part of what makes working in this area so fun and rewarding!

**NS: What are some research challenges that lie ahead in ICTD?**

**EC:** There are tons of them. One of the great things about research in ICTD is that there are fascinating problems everywhere you look, and almost all of them have the potential to measurably improve people’s lives. The core challenge of most ICTD work is design under constraint: constraints in infrastructure (power, connectivity, transportation), financial constraints, educational constraints of users, language constraints, and on and on. Innovation in this landscape is very challenging and it’s quite different from the way in which most technologists approach research. Rather than starting with the bleeding edge of technology, one often has to think about approaches and technologies that meet all these other constraints first. However, ICTD researchers also need to be careful not to get too bogged down in the now, and not be shy about extrapolating out to possible futures and how problems might be solved then. One example is the use of spoken language input and output that works for the myriad languages spoken throughout developing regions. There are huge technical challenges [lack of language corpora for training, variations in dialects, etc.], as well as fascinating UX and design issues.

**NS: MSR India has a great internship program. How can students interested in ICTD work with your team?**

**EC:** Most research internships at MSR India [and TEM] are reserved for Ph.D. students. In TEM, we sometimes offer internships to master’s students, particularly if they are in disciplines other than computer science [e.g., public health, economics, education]. Interested students can learn more about internships by visiting our website [https://research.microsoft.com/en-us/jobs/intern/about_india.aspx].

**References**


**Biography**

Nithya Sambasivan is a user experience researcher at Google.org. She has a Ph.D. in informatics from University of California, Irvine and a master’s in human computer interaction from Georgia Institute of Technology. She has interned at Microsoft Research India, IBM Research TJ Watson, and Nokia Research Center.

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Lessons and Opportunities in ICT4D: Three things I did not know before I started my research

If ICT4D aims to effectively answer the grand challenges it faces, young researchers, in both design and computer science, must be aware of the consequences of how terminology frames this field, be willing to critique and adjust research methods and attend to neglected, challenging concepts.

By Samantha Merritt

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Students embarking upon Information and Communication Technologies (ICT) projects in developing contexts face a challenging subdiscipline within technology research. Creating technology for use in developing areas of the world is neither more complicated nor an advanced version of doing so in other contexts. Additionally, ICT projects in developing contexts will not always be considered a particularly challenging problem space; a community of researchers and professionals are hard at work trying to change that as you read this issue. In fact, I am one of those (student) researchers.

Technology design and human-computer interaction (HCI) work for developing areas of the world (ICT4D or HCH4D) have gained substantial attention in recent years. In journals and at conferences, we typically see two kinds of papers: The ones that discuss the project and how wonderful it was, and the ones that go a little farther to delicately address self-critique or challenges—perhaps even admitting failure. Due to a lively discourse around failure in an open session forum and long paper at the recent ICTD 2012 conference [1], most attendees left with a clear impression that the ICT4D community must diligently curate and fearlessly share insightful failures. Sharing failed projects identifies for the community where improvement is needed and paints a more accurate landscape of ICT4D project success rates. While it is important to share findings and publish about successful projects, it is self-critiques and reflections that are more valuable at this time for ICT4D and HC4D. Why? We simply do not have the issues of designing and deploying technology in these contexts figured out yet.

The entire project of making digital technology for people to use is a relatively new concept in the history of our world. It has developed in a relatively narrow set of places, with fairly high socioeconomic status, education, and
There are many unanswered questions and plenty of space to contribute and participate in the growing community. The challenges I have faced (so far) pale in comparison to the list one could make with an extensive literature review but I would be remiss to keep them to myself.

What’s in a name? For people who work in the ICT4D space, I learned the name matters a great deal. Specifically, the “4D” (or “for development”) is problematic. Both “for” and “development” are troublesome words for reflective practitioners and researchers. I have learned within what I thought was a cohesive set of researchers with a common rhetoric, there was much disagreement and the name of the group itself was not yet settled.

There was a lively discussion about this issue recently as the HCI4D community was forming an official ACM SIGCHI community [2]. There seems to be some disagreement about the correct label that should be used. Ultimately, primarily for the pragmatic reason to standardize for recognition outside the community, the “4D” stuck. Similarly, a related biannual conference, ICTD deliberately removed the “for” in favor of “and” in its own name. This conference and some researchers choose to modify the terminology to change the intentionality that comes with the word “for” in favor of the more neutral interaction implied by the word “and.”

Scholars have also debated issues concerning the concept of “development” (see Toyama and Sambasivan for further reading [3, 4]). Just what kind of development: economic, health, education or skills? Who defines what is developed and what is not? What is developed enough? In publications from our community, as well as development anthropology, non-profit, and government documents, it is clear that the precise identity of the concept “development” has not been settled. It is understandable that we feel uneasy with this word.

The label of the subdiscipline itself serves as an intellectual framing device for the work we do. In HCI, reflexivity is an important component of practice. In being reflexive, researchers often forget to consider looking at the very terms and organizing structures we use. These shape how we think, work and communicate our findings. This is also true for computer science. There is work to be done and questions to be answered about this—there are opportunities in this challenge.

What about methods? ICT4D methods (and respective methodologies) do not always seem to do the work needed for the development context. Though the computer scientists reading this probably will not have to engage in using ethnographically-inspired methods for an ICT4D project, their team members likely will. Ethnography (and other methods derived from the ethnographic discipline) is fairly common for user research and requirements gathering in development contexts. User-centered design and participatory design methods are also commonly reported in literature for the design phase and sometimes earlier as part of user research and requirements gathering.

Many critical, reflexive ICT4D contributions published in ACM venues employing ethnographic, participatory, or other related methods allocate considerable effort explicating methodological concerns and future directions for ICT4D projects regarding method adjustments [4, 5]. Ethnography seems to be at the center of these concerns; though the participatory design discourse also represents a significant body of relevant work. Researchers are reporting challenges...
and complications and modifying their methods or creating entirely new ones. This indicates perhaps ICT4D researchers have some more work to do with methods.

This does not imply that the community of ICT4D researchers does not know what it is doing out there in the field—quite the contrary. There are a lot of inspiring, wonderful, and successful projects published that report using these methods. However, I suggest we systematically examine the methodological (and perhaps even epistemological) roots of our methods used in the field. Doing so might help us better understand some of our reoccurring challenges and even address concerns about working in development contexts where there are looming, tangled concerns about empowerment and culture.

As a student, this can be scary. Novices lean on the structure of methods to help guide our learning and keep us from making too many mistakes along the way. I have learned maybe we should carefully examine just what we are leaning on. What should be done when the effectiveness of our methods are questioned? What should we do when our methods themselves can be objects of study? The answer is of course, that we study them. There is opportunity in this challenge.

Caution: Slippery concepts ahead. There are still some looming and tangled concerns: empowerment and culture.

**Simply developing technology will not solve ICT4D problems, instead, interdisciplinary ICT4D teams should necessarily engage in these complex challenges together.**
Power and culture are just two of many possible slippery concepts encountered in development projects. Politics, ethics, values, religion and conflict are a few others that appear sometimes; though I am certain there is an infinite list. Feminist and postcolonial studies, mentioned earlier, directly address empowerment (or the concept of power more generally) and should be of significant concern to projects in development contexts.

Empowering users and addressing the power relationship between technology designers and the people for which we create digital technology is important in all of technology design. Power relationships become even more important and complex when socioeconomic, political, ethnic and other concerns are foregrounded—as is often the case in ICT4D projects.

Culture is important; lately the HCI design community generally agrees on that point, and the ICT4D community is beginning to seriously engage with culture. Sometimes technology researchers talk about the “technology culture.” We also know that we enact our own culture through our technology use and creation. But what exactly is culture? How is it defined and distinguished? How do technology researchers learn about culture? How does it relate to the development of technology? There are some answers for this in the ICT4D and HCI literature, but no cohesive discourse and little agreement.

In ICT4D projects, culture is central, as research teams are often multicultural and travel/work transnationally. Of course, often the researchers’ do not belong to the same culture for which they are creating technology. Culture matters, but we rarely address it in our work.

We have a lot to learn; things get especially messy when culture and power become entangled and interact with other slippery concepts in our context. Even worse, these concepts are tangled up in every aspect of our work, especially methods. As I alluded at the beginning of this article, even the label we assign our own subdiscipline (ICT4D) is complicated with questions of power. Here is our challenge and opportunity—ICT4D researchers clearly have some very slippery concepts to sort out. I have only named two (empowerment and culture), and in these, many young researchers can carve out a lifetime of contributions explicating these concepts in the global technology terrain, putting those findings into practice, then studying implications, and critiquing the project as it unfolds.

STUDENTS IN ICT4D

Where does that leave a curious student wanting to work in ICT4D? A curious student is hopefully optimistic that there are a lot of interesting challenges and questions waiting to be addressed; and there is probably a healthy yet small dose a fear about choosing to make ICT4D the problem space of a thesis or dissertation. Getting past that fear is a challenge all of its own. Some of my mentors cautioned me about working in this area. ICT4D work can be expensive, time consuming, and, well, challenging. If your passion is to apply the strengths of our field to problems that could significantly make improvements to the quality of life for some of our fellow humans, this work can be extremely rewarding.

The three opportunities I have highlighted are important to computer scientists as well as designers working in ICT4D. If ICT4D aims to effectively answer the grand challenges it faces, researchers in both areas must (1) be aware of the consequences of how terminologies frames this field; (2) willingly critique and adjust research methods; (3) and attend to neglected, challenging concepts (empowerment and culture, for example). As Dodson et al. discovered in their study of ICT4D failures, “technology-centric, goal-diffuse approaches to ICTD contribute to unsatisfactory development results” [1]. Simply developing technology will not solve ICT4D problems, instead, interdisciplinary ICT4D teams should necessarily engage in these complex challenges together.

ICT4D is a great area to apply our collective brain power. The subdiscipline is relatively new and full of things to figure out. It is also established enough that there is a community, papers, conference tracks, and special issues of magazines. We can share our lessons, identify our challenges, and get to work.

References


Biography

Samantha Merritt is a Ph.D. student in the School of Informatics and Computing at Indiana University, Bloomington studying human-computer interaction (HCI). She researches human–computer interaction for development (HCID)—specifically the practice of technology design in developing regions, specializing in sub-Saharan Africa. She is interested in the future direction of relevant theories, methodologies, and design practices in cross cultural projects. Feel free to contact her at samanthamerr@indiana.edu or go to http://samanthamerritt.com/blog/.
A digital divide exists between the global North and South, otherwise known as economically developed nations versus less resourced countries. The same could be said within the targeted discipline of Information and Communication Technologies for Development (ICTD). Research efforts coming from African-based academics in this area represent a small percentage, relative to its population, and especially when being published in academic journals or presented at ICTD conferences [1]. This is also the case in other disciplines for similar research outputs produced by South African universities.

Such a measurement is limited given that much of the research efforts written at universities may not be through journals, but in other forms [2]. However, even with the inclusion of policy briefs and grey literature within scholarly communication, emerging scholars remain at unique stages of learning and changing the ecosystem; being either the determinacy to keep the norm (i.e. academic papers accepted in Thomson-Reuters Web of Knowledge database, formerly known as the Institute for Scientific Information or ISI) or aiming for alternative or more relevant developmental choices in scholarly communication.

Given this under-representation in global academia, the ICTD research field threatens to weaken the true diversity and participation of African researchers. The current field may find itself influencing and leveraging the benefits of ICT research and theory within a smaller membership of experts in various ICTD sub- or multidiscipline academic communities. The minimal formulation and influence from Africa to global knowledge systems means the knowledge produced today comes from the side that is heard the most frequently, underlining much of the lesser-written space of Africa-based theory and research.

In an attempt to ameliorate this situation and try to build a field of African-based researchers in ICTD, the following recommendations have been proposed [3]:

• The global ICTD community must recognize the major intellectual contributions that are overlooked if African-based institutions and academics do not participate in global academic spheres.

• Institutions should deliver methods to change such imbalances and allow African ICT researchers to gain better reach and range from their own unique research.

The first recommendation may be obvious to researchers, yet there is a surprising non-recognition of quality global South-based researchers and it comes at a loss to our ICTD community. I could be risking myself in speaking on the political economy of academia, but human behavior can be selfish. There might be an institutional loss of prestige to lower the influence of currently global and well-recognized institutions in the speaking or writing forum. Further, there could be the overwhelming thought that when trying to address the poverty of the research output diversity in our discipline, one would not know where to start. Fear cannot be misjudged; nor can trust, as well as where or who is best to identify the potential for good ICTD research to propagate. Additionally, what does it take for mutual respect by North-South or South-South
relationships to allow the “unknown” or emerging scholars from the global South into a research sphere where one may not readily open up? The global academic space may work counter to the one which wants to support scholars of the South in order for individuals to maintain their own research prestige and resources, which make them “experts” and others not.

Nevertheless, such extreme views of “expert fiefdoms” may not run in line with the developmental objectives within a current movement of openness and scholarly creations through open collaborations. The second recommendation assumes recognition of the first recommendation (i.e. recognition of global South-based researchers) and puts its trust in forms of institutional interventions, which counters the current status quo. Institutions may come in various forms, from university or higher educational boards’ affirmative action, to smaller cases of conference resource subsidies. By putting efforts and resources to include African-based researchers into the ICTD research network, this supports the claims that building the capacity of networking would help enhance opportunities. Of course, inclusion does not come instantly. Effort even from the ground up or in the global South must come within a timed pace that recognizes historical injustices and by choice of individuals and/or its community, which takes into account certain environmental conditions (both internal and external). Such changes in conditions are working in conjunction with interventions such as network building and using human capacity to lobby for societal welfare improvements. Such interventions are based on a deeper assumption that some equitable platform is provided to researchers of the South thereby enriching them to play a part in the ICTD academic community.

Nevertheless, such extreme views of “expert fiefdoms” may not run in line with the developmental objectives within a current movement of openness and scholarly creations through open collaborations. The second recommendation assumes recognition of the first recommendation (i.e. recognition of global South-based researchers) and puts its trust in forms of institutional interventions, which counters the current status quo. Institutions may come in various forms, from university or higher educational boards’ affirmative action, to smaller cases of conference resource subsidies. By putting efforts and resources to include African-based researchers into the ICTD research network, this supports the claims that building the capacity of networking would help enhance opportunities. Of course, inclusion does not come instantly. Effort even from the ground up or in the global South must come within a timed pace that recognizes historical injustices and by choice of individuals and/or its community, which takes into account certain environmental conditions (both internal and external). Such changes in conditions are working in conjunction with interventions such as network building and using human capacity to lobby for societal welfare improvements. Such interventions are based on a deeper assumption that some equitable platform is provided to researchers of the South thereby enriching them to play a part in the ICTD academic community.

Emerging scholars need not wait for mechanisms (i.e. mentorship programs, institutional repositories, improved learning processes) and instead should take it upon themselves to build their own awareness and network in a currently isolated field of ICTD research within Africa. There are incredible constraints that affect

We walked away with a starting discussion around what is Africa-based theory and concepts in ICTD, particularly around the capabilities approach, human computer interactions design (HCI-design), and community or Ubuntu concepts.
emerging scholars and researchers in Africa from meeting their publishing or research potential. Yet the enthusiasm of emerging scholars, who are naturally using existing social media and basic email list-serve tools, can launch a more important keen group of young scholars—the human capital—to bring attention to the ICTD research and applied work happening in parts of Africa. While several African ICTD networks have currently been formed, there are few which are started voluntarily together by young emerging scholars and are dedicated to ICTD African research. This article takes one interventionist angle of young emerging scholars based in African institutions whose ground-up virtual network hopes to start a more organic method of continental shared dialogue and hopes to kick-start for new relevant ICTD research or collaborations.

**METHODOLOGY**

The premise of the initial network was the belief that those who remain on the “ground” or work in the conditions of the global South (in this case, sub-Saharan Africa) may well be the most relevant in resolving the developmental problems which plague their direct and everyday interactions. The action research interventions are iterative and based on the needs requested by the network members and also look for ways suggested by its members to maintain and encourage active membership participation. The maintenance of the network relies on the action and emails of the members. The participation also considers that learning occurs when members are prepared to engage and contribute to activities whether it is organizing conference papers, sessions, or applying for grants. Only when an individual member decides to make the effort to participate, when they are ready, will be the most transformative and gain agency from being a member in the network.

**ORIGINS OF THE AFRICAN ICTD RESEARCH NETWORK (ICTD2010 LONDON)**

The start of the network was initiated in London in December 2010 at the international conference on Information and Communication Technologies and Development (ICTD2010). As the first plenary presentation of the conference, our group presented what Kentaro Toyama has deemed in his blog as a “call to arms.” In the paper titled, “ICTD Research by Africans: Origins, Interests and Impact,” my colleagues and I brought up the discrepancy of African-based authors in academic papers in the ICTD space. We were interested to know what academic contributions Africans in ICTD were making. From our exploratory review of ISI World of Knowledge publications, approximately 9 percent of outputs from the chosen databases came from African institutions and mainly from South Africa—this was a review of 1,633 articles in ICTD and development topics. In fact, in the same paper, we also identified the International Association of Media and Communication Research (IAMCR) “communications for development” as one of the major themes. In this conference, the trend was about 5-8 percent of papers from the main conference coming from African-based authors and concentrating in HIV/AIDS or health communications. We believe the program chairs of ICTD2010 placed our Africa presentation first on purpose to bring to the attention of the ICTD community the communal detriment related to the lack of African-based researchers on the agenda.

After the presentation, we drew quite a bit of stir from a well-read blogger, Erik Hersman, known as “White African” on his blog [4], as well as from more mainstream form research media, like SciNet [5]. After our conference presentation, a group of emerging researchers from Africa gathered together at a lunch hour to discuss ways to keep in touch with research and events occurring within the continent and beyond around ICTD research. At the meeting we established our network goals of:

- Amplifying individual voices and raising the visibility of African ICTD Africa-based scholars, practitioners, and government officials meet for the first time to talk about ICTD issues on the continent.
By 2011, the research paper from ICTD2010 was converted into a popular magazine article in ACM’s *Interactions* magazine and the network had developed a Google list-serv, a blog website, and brought together an open session for the following ICTD2012 conference in Atlanta, GA. It played more as an advocacy piece, stating that since the conference we have initiated the first virtual network of Africa-based emerging scholars in ICTD who are most interested in staying connected and informed about the issues of ICTD and being readily available to explore research in a collaborative direction.

In March 2012, the network had organized an open session that had the objective of trying to initiate a dialogue on practical means by which we can address the under-representation of African researchers in formal ICTD academic discourse. We opened up an opportunity for researchers to send us some of their ideas around new or existing fundamental theoretical concepts, methodologies, and gaps in ICTD research in Africa based on African researcher perspectives. At the 50- to 60-person session, we walked away with a starting discussion around what is Africa-based theory and concepts in ICTD, particularly around the capabilities approach, human computer interactions design (HCI-design), and community or Ubuntu concepts. Publishing was also a topic for the audience to give their opinion, circulating around what their experiences had been and what techniques they deemed to work in improving African publishing. Overall, traction has been gained in deriving some of the African based research in ICTD, which emerging scholars are interested in and would like to put forward for the next conference to take place in Cape Town, South Africa in December 2013. Some of the future ideas, which evolved from the ICTD2012 Atlanta meeting, included:

- exploring development of papers around the misrepresentation of Africa in ICTD research,
- ICT and African languages,
- Africa-based theory and conceptual frameworks,
- ICTs, Africa and faith, and
- the expansion into the Francophone sessions.

**DESCRIPTION**

The network is completely voluntary and virtual, it is not an established formal entity tied to a non-governmental organization (NGO) or any other organization. Of an emerging scholar network, the virtual membership today consists of around 70 members (after the ICTD2012 Atlanta conference). Previous to the conference, we had 45 members who all belonged to institutions in sub-Saharan Africa, mainly from South Africa (institutional affiliations include the University of Cape Town and Monash University), Nigeria, Ghana, and East Africa. These members were mainly Ph.D. candidates, some junior faculty members, and post-doctoral students. The premise of having a majority located at African-based institutions is to note the various struggles understood on the continent and to develop in the African voice, which was distinct in the academic world. After the Atlanta conference, we have opened up membership to include senior researchers or faculty based in Africa as well as African students doing their Ph.D. studies in the U.S. The feeling was to acknowledge the many friends and supporters of the global South who wish to strongly support the initiatives of the South and wish to be involved in the dialogue of southern-based research. And fair enough, it is not only through a network within the continent, which will allow us to develop as a stronger entity, but also through the support of others. Nevertheless, the understanding of ensuring that contextual situations where ever research may take place in

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The network’s first ICTD2012 open session ends well, with many new members and research ideas to take to the Cape Town conference in 2013.

An African Researchers ICTD network would allow for more research collaboration across the continent as well as with others based in the global South.
Emerging scholars need not wait for mechanisms and instead should take it upon themselves to build their own awareness and network in a currently isolated field of ICTD research within Africa.

Emerging scholars are further down on the academic rung of gaining access to the ICTD community. They must work hard to build their capacity in research as well as be familiar with the trends. Nevertheless, some of our network researchers are attempting to play the global North knowledge system by publishing in various journals and presenting at targeted conferences. Many of the network member projects are also pursuing “developmental impact” from building a CV solely by mobile phone (Umemli.org), to providing a virtual intermediary system to match informal workers to work (Open Air Labour Market Exchange) [6]. There is an imbalance of the published works versus those that are “hands-on” and meeting the demands of the most disadvantaged [2]. In hosting a virtual group, we are starting to recognize a group of young African scholars who are interested in ICTD and that the network works toward contributing to the improvement of the member’s academic status or ambition of a better world through positive use of ICTs in development projects or intent.

**DISCUSSION**

The idea to create a group of young scholars from Africa working in ICTD researchers came organically; there is a passion to better understand the research field, as well as have the African voice heard more prominently. In gathering as a group at lunch at the Royal Holloway in 2010, we then launched various communication medians (blogs, list-servs, Skype meetings, and regular correspondence).

As a result of the last few years, has this network contributed to building research capacity? At the moment, the feedback from the network list-serv may not be enough evidence to determine the contributions of the network to the research capacity of emerging scholars in the African network. Nevertheless, the initiative is self-driven by its emerging African scholars who volunteer their time and enthusiasm to see that Africa is placed on the map in recognition of ICTD research work.

**WAY FORWARD**

The research network has great potential to expand its activities in collaboration. For example, as aligned with another short-term goal, an organizing committee has already started preparation for the next ICTD conference to take place in December 2013 in Cape Town. As part of these preparations, a proposal is being developed by the committee to establish a pre-conference for emerging scholars from the global South. This pre-conference would have an opportunity for researchers to read and discuss the proceedings of the conference in a critical way, present some of their own research or work in progress either in one of the conference formats (poster, open session paper, or plenary), and participate in an informed manner for the duration of the conference. As a secondary output, the researchers will have a chance to meet and network with local global South-based researchers. In the long term, one would hope that an African Researchers ICTD network would allow for more research collaboration across the continent as well as with others based in the global South.

**References**


**Biography**

Kathleen Diga is a Ph.D. candidate under Professor Julian May at the Institute for Social Development, University of the Western Cape, in Cape Town, South Africa. Her main focus of research is in the poverty and economic dimensions of information and communication technologies for development (ICT4D). Diga currently works as a project manager at the University of KwaZulu-Natal, Durban, South Africa, and previously worked as a research officer at the International Development Research Centre (IDRC) under the ICT4D Africa (Acacia) initiative in Johannesburg, South Africa and Nairobi, Kenya.
User Experience Practices in Nairobi’s iHub Community

How a forthcoming user experience (UX) lab will meet the needs of the African technology community.

By Mark Kamau, Angela Crandall, and Kagonya Awori

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At the time of this writing, the iHub community is preparing to launch one of the first user experience (UX) labs in Africa. UX refers to the way a person feels about a particular product or system, capturing not only user perceptions about physical features, but also practical aspects such as usability [1]. Good UX is more than just good design; it’s about solving a user problem. Ensuring a product has good UX is important because UX can influence customer retention and loyalty, attract (or reduce) new users, affect product efficiency, and, most importantly, increase overall user satisfaction with a particular product or service [2].

Studying and understanding UX is now a common practice at many of the world’s leading technology companies including Ericsson, Samsung, and Google. However, such UX Labs have yet to emerge in some of the countries that need them the most. The vast majority of design programs in Kenya, and Africa in general, are not properly teaching graphic design approaches and design thinking. Instead, many of these institutions only cover tool use (e.g. how to use Adobe Illustrator). This has put Kenyans at a disadvantage when competing on a global scale in the design sector; most of us are not able to compete because we are not performing at a global standard. In order for Kenyans to perform at such a level, there is a dire need for some intervention. That intervention is the new iHub UX Lab.

The vision for the iHub UX lab is to develop a design thinking and user experience culture in the region in order to attract, develop, and retain a vibrant base of world-class talent that will increase in both size and complexity. The major challenge we seek to address is the level and quality of graphic designers that come out of Africa. We’ve identified that there are just not enough good graphic designers for each developer that works in the African tech environment; rough estimates for the Nairobi tech scene put it at about 20 developers for each average graphic designer.

As we planned for the iHub UX Lab, we wanted to engage the tech community to better understand their current practices of how they get feedback from their users. In particular, we wanted to validate our observations and get more information on the types of knowledge that iHub members currently employ when assessing their users’ experience with their products. The iHub team therefore undertook a brief study with the aim of understanding the methods currently used by the iHub community to identify and correct UX problems. Ultimately, the study was intended to
by providing training on UX methods and different design approaches. For example, we found many people identify product problems through observation of system flaws and pinpointing of malfunctions. This is a typical “developer” mind-set; that is, if the code is broken or if there is a bug, that is when there is a problem. This mind-set needs to be broadened to incorporate design best practices including design thinking and other industry standard practical training.

In order for Kenyans to perform at such a level, there is a dire need for some intervention. That intervention is the new iHub UX Lab.

The open-ended electronic survey was run in May 2012 and elicited 108 responses from a variety of community members including designers, developers, programmers, and solution providers. We designed our survey to understand how respondents identified problems with their systems and tools; how they later go about solving those problems; how they measure “success” in a product; where they go to learn; and whether or not they actually know the users of their products. In the following sections, we review our findings and consider how they will inform the design of the iHub UX Lab.

CURRENT UX PRACTICES
Our first set of findings allowed us to understand how the iHub community currently identifies problems. A typical UX approach is to allow potential users to try out a product and ask them for feedback [3]. However, only a handful of our respondents mentioned user testing and feedback as part of their current practice (e.g., “I give [my product to] a user who doesn’t have much knowledge and I hear his/her complaints!”). This suggests there is an opportunity to encourage user involvement.

MEASURES OF SUCCESS
We asked the iHub community to describe how they measured a “successful” product. A promising result was almost one in every three respondents measured success based on the satisfaction of end users, suggesting user satisfaction is clearly an important consideration for the iHub community. This idea that the opinion of the users is most important (as...
Research at Nairobi’s iHub: Discovery and Sharing

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Nairobi’s Innovation Hub, more famously known as the iHub, is an open space created to provide the tech community—technology entrepreneurs, programmers, designers, and researchers—with an environment that enables them to think without regard to the proverbial box and to draw on iHub resources such as work space, training, and fellow community members for the purpose of solving citizen needs through novel technologies. To meet the ever-increasing needs of the community, the iHub has expanded and created several initiatives that supplement iHub Core—iHub Consulting, iHub UX Lab, iHub Cluster and iHub Research.

iHub Research recognizes the need for quantitative and qualitative research from Africa and was born with the mandate to spearhead technology research in East Africa in three distinct ways.

KNOWLEDGE
The foundational reason for carrying out research is to generate new knowledge. iHub Research seeks to inform decision making processes through our work, from the policy making level to daily decision-making by tech entrepreneurs. Our M-Governance project, supported by funding from the Swedish Program for ICT in Developing Regions (SPIDER) and Ford Foundation, is studying the use of technology to help the government deliver essential services, such as water, to citizens. The outcomes of this study will help to inform water-related policy. The challenge with such projects is to ensure that the results are taken on board and utilized fully by policy makers.

DISCOVERY
It is after acquiring knowledge that we can decipher nuances from it. Whether carrying out research to test a theory or building on previous research findings, research yields new discoveries. The ICT Hub study is a research series that is uncovering the factors that lead to successful ICT Hubs in Africa, with a focus on the role of the hubs in fostering innovative entrepreneurship. The study began with iHub before profiling Hive Colab in Uganda. The project team is about to release its third profile, ActivSpaces in Cameroon. Another area of our research, the Open Data project, seeks to discover the possibilities that lie in exploring datasets released for public use by the government. Securing funding to conduct such studies can be a major challenge, especially if it is an in-house study such as the ICT Hub study. Additionally, convincing stakeholders to participate in research where they cannot see the tangible benefits proves difficult, and reduces the scope for discovery.

SHARING
Upon acquiring knowledge or discovery, the natural next step is to share. Ultimately, all studies carried out by iHub Research are for the benefit of the community, whether specific to the technology community or the nation at large. The research arm aims to share the knowledge that it has acquired through infographics, project reports and blogs, so that stories about the community can be told. By doing so, we create a space for researchers to tell their own stories, foster the visibility of African researchers, and improve the quality of tech research and publication output from Africa. The greatest challenge lies in ensuring that all interested parties, including the citizens being interviewed on the ground, receive the relevant information they need from our findings, packaged in the appropriate way. Our hope is that through our research, new solutions can be discovered and applied to solve real, on-the-ground needs.

Thus, iHub Research aims to create new knowledge, discovery, and share with the East African community and beyond. For more information, please visit www.research.ihub.co.ke.

—By Angela Crandall and Rhoda Omenya

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opposed to any defined metrics or financial milestones) falls in line with our new UX Lab, which, at its core, values human-centred design and engaging the end user to determine how a product should be built, tweaked, and eventually judged. In other words, there is clearly an appetite within the community for learning and enhancing the UX culture. Our UX Training Room, where we will teach the principles of UX and how it is relevant to a particular product or start-up, will help the iHub community to have a clearer idea about which elements of their product are effective, and will help them to identify elements that still need to be improved.

TECHNOLOGIES FOR LEARNING
In order to determine what educational resources the UX Lab and Training Room should provide, we wanted to explore which resources the iHub community currently uses for their on-going education. We found almost all of the iHub respondents primarily use the Internet to enhance their personal skills. Again, this is quite typical of developers who often troubleshoot product bugs using search engines and online forums with other developers. Three-quarters of respondents used books, and half gained new insights and skills from videos and in workshops. Only a small handful used networking opportunities, consultation, and brainstorms with others.

This finding reveals a gap in linking the iHub community to competent professionals from around the world. Rather than solely relying on Internet resources, the new UX Lab should build a network of local and international design experts, who will teach master classes that will enable the design and tech community to improve their level of design knowledge. Corporate subscription to professional and academic online UX groups and libraries is also a recommended step for the UX Lab.

KNOWING END USERS
We rounded off our survey by explor-
ing whether respondents were familiar with the end users of their products and systems. Over half of respondents believe that they know their end users, with many of these respondents reporting the use of a periodic survey or market research to collect statistics on their users. Another third identified their end users through direct interaction with them when selling their product.

However, another half of the iHub community respondents stated they do not know their end users. This is quite alarming as it raises a fundamental question of how developers and designers create their products if they do not have a targeted user in mind. Our new UX Lab will therefore need to teach developers and designers how to observe, understand, and empathize with their end users.

As emphasized throughout this article, training must form the backbone of the new UX Lab. In developing master class training we’ve involved the design community to help decide on our areas of design intervention, and we hope to foster new areas of competence as a result of ethnographically engaging the community within which we live and work. Feedback and continuous learning from the tech community will ensure appropriate adaptation of both the content and context of the master classes.

In conjunction with the training we envision, which we hope will enable a UX culture to take root and grow within the tech community, our UX testing facility will help develop a global standard design community and spearhead the development of a user experience and design thinking culture in Africa.

CONCLUSION

The survey allowed us to understand the current UX practices of the iHub community in Nairobi, Kenya, and have directly informed the proposed layout of our UX Lab (as shown in Figure 1). Although there is a clear interest in developing products that meet the needs of users, many members of the iHub community are still unsure about the design approaches to use and have not yet learned enough about UX design processes. This suggests the community will benefit from a dedicated training and testing space where technologists and potential users come together to develop a design thinking and user experience culture in the region.

Design is a way of thinking; it is a way of doing things and solving problems. Unfortunately, not enough designers in Africa have learned a toolkit of processes to use for good design. This need has become even more apparent as the demand to design systems (through mobile and web applications) grows across the continent. The iHub UX Lab will build a wide network around the world to help develop a globally competitive African design community.

References


Biographies

Mark Kamau is iHub’s user experience lab manager. He has been working in the multimedia design industry for over 10 years with experience in several African and European countries, including Berlin and Amsterdam. Kamau is passionate about user-centred design. He can be reached at mark@ihub.co.ke.

Angela Crandall is iHub’s research project manager. She specializes in the use of ICT in the East African agricultural sector, having conducted research for a Raines fellowship in 2009 and a Fulbright fellowship in 2010–2011. Crandall is also interested in understanding mobile use at the base of the pyramid and the appropriate use of ICT for development. She can be reached at angelac@ihub.co.ke.

Kagonya Awori is an independent user experience researcher based in Nairobi, who works with iHub on several research projects. She holds a dual master’s degree in human-computer interaction from Carnegie Mellon University and the University of Madeira, Portugal. Her research interests include local content generation in developing communities, localization and globalization, and HCI for less industrialized communities. Awori can be reached at kagonya@ihub.co.ke.
Matthew Kam
Technology, Impact and Development

BY RYAN KELLY
DOI: 10.1145/2382856.2382876

Growing up as a teenager, Matthew Kam didn’t always plan to work so closely with technology. Instead, his ambition was to become a development economist who could address problems related to global poverty. But it was while studying economics at the University of California, Berkeley that Kam realized his passion for global development could be combined with his childhood hobby in computer programming and robotics. His senior honors thesis in economics examined the impact of donating computers to low-income households, and it was this desire to see real impact on the ground that shifted Kam toward technology. “When you’re an economist, it’s really hard to effect change,” he explains. “But with technology, you can work at the grassroots level and you don’t have to wait for support from policymakers to get things done. When I started out, there was really no such thing as ICT for development, so that was probably the computer scientist in me, figuring out a much more practical way to make an impact.”

Kam later decided to stay at Berkeley for a doctorate in computer science. One of his first projects was LivNotes; a wireless handheld tablet system intended to support group learning in classrooms. Although he is modest about the project’s success, Kam admits LivNotes was instrumental in directing his long-term focus towards educational technologies. Later, Kam began to realize that many of the problems he was trying to solve were not technical computer science issues but instead called for an in-depth understanding of education. He describes this as an epiphany, eventually leading to his pursuit of a doctoral minor in education where he studied topics that include literacy studies, the psychology of reading, and second-language acquisition.

After graduating, Kam joined the prestigious Human-Computer Interaction Institute at Carnegie Mellon University as an assistant professor. Since then, his research focus has remained in educational technologies, and he has overseen numerous projects for developing and underserved contexts. One project that remains close to Kam’s heart is his work on mobile literacy learning in India. MILLIE is a project that aims to help poor children acquire English literacy using educational games designed for low-cost cellphones.

This desire for real-world change has fuelled his recent move to the American Institutes for Research’s International Development Program in Washington D.C., where he works as the senior technology strategist advising international aid organizations and the donor community.

Talking with Kam, it soon becomes clear that he really wants to make a difference in people’s lives, as opposed to focusing on the publishing mill often characteristic of academia. “Academics have done a fantastic job in raising the discourse about the role of technology in society and community development. But despite our publications and scholarly activities, it feels as if we have been mostly talking among ourselves. These important ideas need to get out to the rest of the world.” He is equally introspective about the differences between academia and his new role: “A university is an excellent place to get the initial training, in terms of an undergraduate or graduate program. But you have more scope to make a difference in an international aid organization, where you work with government agencies to get things done. Likewise, from a research standpoint, working out there in developing communities, you get to put the research base under a stress test. You gain a first-hand appreciation for what’s missing in the literature, and the policy and other real-world constraints that a research agenda ought to account for.”

One of his other goals is to increase the prominence of ICTD as an area of professional practice by focusing on long-term career prospects: “Students have to be really brave to do graduate studies related to ICTD,” he says. “People doing ICTD projects often end up going elsewhere because they can’t find enough satisfying jobs in ICTD after they graduate. What we really need to do is to advance the thinking among donor agencies and other organizations on effective approaches for ICTD.” Kam has also been involved in growing the ICTD academic community.

In the future, he wants to bring more members—both students and experienced researchers and practitioners—into the fold of ICTD. Kam is also excited about standing for election in ACM SIGCHI to coalesce the ICTD community further. “At the end of the day, international development is about engaging with communities, being out there and changing lives. Students who are passionate about that will find a welcome home in the ICTD community.”

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ideas, but rather the extremely high barriers to entry. In order to take advantage of mobile band spectrums for example, licenses have to be acquired and regulation must be navigated in order to get an access point. Wi-Fi on the other hand has a much higher capacity and much lower costs associated with it, but is limited in coverage. With this in mind, I chose to work on this topic for my class. I joined a project called “FabFi” (http://fabfi.fabfolk.com/), which enables individuals and communities to fabricate and deploy their own ICT infrastructure to serve local needs. FabFi provides long-range Wi-Fi connectivity using low cost materials to boost signals. Communities can also use this technology to build and manage wireless mesh networks for their own use. FabFi operates a pilot program in Nairobi, Kenya and is in the process of rolling out a large-scale network in Afghanistan. My specific role in the project was to help create a billing system that would keep track of bandwidth use and also provide a simple cashless means of payment.

As part of the extended fieldwork for the class, this past January I had the opportunity to work with FabFi in Nairobi. I was piloting a system that would integrate M-Pesa mobile money payments with the FabFi network. M-Pesa is the revolutionary mobile money transfer system developed in Kenya by mobile network operator Safaricom. It has quickly become a necessary convenience in daily life in Kenya and there are attempts to replicate the model in other African countries. In the context of FabFi, instead of physically seeking a FabFi agent to make a direct payment and then have them restore your network access, or buying a scratch card to key in and restore access, the goal of this pilot was simple. Users with a registered M-Pesa account would be able to send payments to FabFi to automatically have

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**LabZ**

**D-Lab-ICT: Spreading ICT Innovation**

**Cambridge, Massachusetts**

In the autumn of 2011, I enrolled in an MIT course called D-Lab-ICT, which focuses on information and communication technologies. The goal of D-Lab is to engage students in applying technology to solve challenges in developing countries. While one approach to this process is to design new technologies from the ground up, specifically with developing country contexts in mind, another approach has been to adapt technologies already present in developing countries to address new challenges. When talking about information communication technology (ICT) developing countries have often been pioneers, making great leaps and even surpassing more developed countries in usage and innovation, particularly in mobile communications.

The main limitation in innovation in ICT has not been hardware or devices, or even entrepreneurship and
ICT for Education

The idea of using computers in education has a fairly long history, but the role they play has changed over the years. Early uses often involved using a computer in an instructional capacity, effectively playing the role of the teacher transferring knowledge to an individual. Over time, common use has involved many more collaborative and online elements. The ability for students to work together and to receive quicker feedback from instructors in a classroom setting shows promise for improving the acquisition of knowledge. There are additional benefits that come with the ability to use the same technology outside of the classroom to maintain interaction with classmates and access to external educational resources. Apple tried to take advantage of the rapidly developing educational technology market in the late 1990s by introducing the eMate 300, but the technology was still too expensive to take off. The eMate was discontinued just one year after its release. The more recent One Laptop per Child (OLPC) project has, however, seen some success with its inexpensive XO-1 laptop. OLPC is targeting education, but is focused on developing nations and other underdeveloped regions. As the technology continues to get cheaper, such products will only become more accessible to those in need.

—Finn Kuusisto

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<td>Display</td>
<td>6.8” 480x320</td>
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<td>CPU</td>
<td>25 MHz, ARM 710a</td>
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<tr>
<td>RAM</td>
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<tr>
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<tr>
<td>Target Market</td>
<td>Education</td>
</tr>
</tbody>
</table>

Design Goals
Low-cost
Low-cost, low-power, small, rugged, open-source

In 2001, 50 percent of wired broadband subscribers in the world were in China.

In developed countries have Internet access, compared with 20 percent of households in developing countries.

their accounts restored or updated. This adds convenience to the customer who is no longer constrained by timing and distance, and reduces the costs of the network operators tasked with handling cash payments.

This integration typifies the kinds of innovations that are set to bring about dramatic changes in the way businesses model themselves, while opening up immense new opportunities for entrepreneurs. Where Internet access is limited, such feature phone applications can do for developing countries what online payment methods did for the developing world. As FabFi seeks to expand, bringing Wi-Fi connectivity to remote areas, the stage is indeed being set to channel the demonstrated innovative ability of higher bandwidth applications to address developing country needs—all served by open source ware and open source techniques. The impact could indeed be significant.

My experience working with the D-Lab class and FabFi project has given me the opportunity to learn about extending advanced technologies using low cost techniques, and also to meet innovative young entrepreneurs implementing their visions, which has been a great inspiration. It is perhaps most interesting to see how engineering innovation from students in the U.S. can be combined with locally-grown innovation in Kenya to create new business models that can be exported globally.

I hope educational programs such as these help foster stronger collaboration between engineering students, entrepreneurs, and ICT organizations around the world.

Biography
Jonathan Kola recently graduated from Harvard College with a degree in electrical engineering and computer science. He is currently working with a startup called Wecyclers that provides incentives to low-income households in Lagos, Nigeria to recycle their waste.
Iterative Numerical Methods for Nonlinear Systems

BY MARINKA ZITNIK

A mathematical model characterizes the system using mathematical language and concepts. Mathematical modeling is adopted not only in engineering disciplines, but is also intensively used in social and natural sciences. Its insightful applications may help to explain the observed system, study system’s effects, and predict future behavior. As such, modeling in the broad sense can potentially create great value for disadvantaged populations in numerous areas of human endeavor.

Here we present some valuable techniques in mathematical modeling by outlining basic, iterative numerical methods for solving nonlinear systems of equations.

Suppose we are given a system of nonlinear equations

\[ \begin{align*}
    f_1(x_1, x_2, \ldots, x_n) &= 0 \\
    f_2(x_1, x_2, \ldots, x_n) &= 0 \\
    \vdots \\
    f_k(x_1, x_2, \ldots, x_n) &= 0;
\end{align*} \]

written shortly as \( F(x) = 0 \), where \( x \in \mathbb{R}^n \) and \( F: \mathbb{R}^n \rightarrow \mathbb{R}^n \).

For the vast majority of practical problems no exact solution to the system in Eq. 1 can be found by a direct method, therefore iterative methods have been proposed. These have some advantages over direct methods.

Firstly, if the system of equations is large and sparse, iterative methods reduce memory usage whereas direct methods may eliminate the sparseness of the matrix representation. Further, in iterative methods we can influence the accuracy of the computed result. A higher number of executed iteration steps implies a better approximation at the cost of a greater amount of resources being spent. When a sufficient solution requires only a few exact decimal places, we can do only so many steps of an iterative method as necessary to reach proper accuracy. This is not an option in direct methods, as we always spend the same number of iteration steps to get to the result.

In a high-dimensional system determining the initial approximation of the solution is difficult without knowing the system’s background. In the case of searching roots of a simple low-dimensional function we can use the graphical representation for estimating the initial values. If the system consists of two equations, one can simply look for an intersection of two implicitly given functions. The generalization is more complicated and can utilize the use of numerical continuation, variational methods, linear model approximation, and system reductions.

We use presented techniques to numerically solve a nonlinear complex equation

\[ z^n + z + 1 = 0, \]

where \( z \) is a complex variable. Using standard substitution \( z = x + iy; x, y \in \mathbb{R} \), Eq. 2 is rewritten to an equivalent real equations

\[ x^n - 6x^3y^2 + x + y^4 + 1 = 0 \]
\[ 4x^3y - 4xy^3 + y = 0; \]

which we have yet to solve. The methods for solving nonlinear systems overlap in their analysis and motivation with optimization techniques discussed in Burden et. al. and Kelley [1, 2]. Characteristics such as trust regions, line searches, and inexact solution of the linear algebra subproblems at each iteration step are vital in both optimization and solving nonlinear systems, as are derivative evaluation and global convergence.

Prerequisites

Our implementation is in the Python programming language using NumPy, an efficient Python scientific computing extension, which adds support for large multi-dimensional arrays and matrices and contains a library of mathematical functions. We begin by importing the needed functions.

```python
from numpy import mat, from_numpy, linalg, import solve, norm
```

Jacobi Iteration

Jacobi iteration is a generalization of ordinary iteration method. The system \( F(x) = 0 \) is rewritten to an equivalent form \( x = G(x) \), where \( G: \mathbb{R}^n \rightarrow \mathbb{R}^n \) is a \( n \)-dimensional function. The Jacobi iteration forms a sequence of approximations by iteratively applying the function \( G \) on the current approximation to the solution, such that the result at step \( r + 1 \) is given by formula \( x^{(r+1)} = G(x^{(r)}) \). The following Python function reformulates the system of equations in a way to comply with the denition of the function \( G \). (See Definition 1.)

```python
def G(X):
    return mat([-X[0,0]**4+6*X[0,0]**2*X[1,0]**2-X[1,0]**4-1,
                -4*X[0,0]**3*X[1,0]+4*X[0,0]+X[1,0]**3]).T
```

The order of convergence depends on the properties of the Jacobian matrix of function \( F \), which is the matrix of function's first order partial derivatives with respect to the variable vector \( x \). The sufficient condition for the convergence independent of the initial value is the spectral radius of the Jacobian matrix being less than one.

The Jacobi iteration method is a simple parallel algorithm as computations of components \( x_i^{(r)} \), \( i = 1, \ldots, n \) are independent of each other and little effort is needed to reduce execution time by running them in separate parallel tasks. If one computes components of vector \( x^{(r)} \) in order and takes the newly computed values \( x_1^{(r)}, \ldots, x_n^{(r)} \) into account when computing \( x_i^{(r)} \), the Jacobi iteration is renamed the Seidl iteration method. Seidl iteration usually converges faster.
although some counterexamples exist. Below is the implementation of the Jacobi iteration method through function `jacobi_iteration`.

**Newton Method**

The Newton method lies at the heart of many important algorithms. It forms the sequence \( x^{(n+1)} = x^{(n)} - J_{x}^{-1}F(x^{(n)}) \); \( r = 0, 1, ... \) and \( J_{x}[x^{(0)}] \) represent the Jacobian matrix. Instead of computing the inverse Jacobian matrix, one solves the system of linear equations, which is numerically more stable and efficient.

The Newton method is derived using Taylor series expansion [3, 4]. The order of convergence is quadratic near the simple root of nonlinear equation, but a good initial value is needed to achieve it. The chaotic behavior of the Newton method and its sensitive dependence on starting point is depicted in Figure 1. It shows a map of starting points and which solution they converge to with the equation Eq. 2.

The boundary is a fractal and paradoxically between any two colors in the boundary there exists the third. Several variations of the Newton method were developed in the search of alternative algorithms such as the relaxed Newton method.

The Python function \( F \) expresses the nonlinear system from Eq. 3 and Python function named \( JF \) implements the Jacobian matrix of the system. [See Definition 2]

The Newton method is implemented in function `newton`, which takes as parameters the function describing the nonlinear system \( F \) and its Jacobian matrix \( JF \) together with the initial value to the solution of \( Fx0 \), maximum number of executed iteration steps \( k \) and acceptable tolerance \( tol \), the latter two being used as a stopping condition.

**Quasi-Newton Methods**

The Newton method is computationally intensive when the number of equations \( n \) is large. If the Jacobian matrix is full, one needs to calculate \( n^2 \) partial derivatives in each step of the algorithm and then solve the linear system with matrix size of \( n \times n \) which might require as much as \( \mathcal{O}(n^3) \) operations. For this reason, and because we often do not know the partial derivatives, we sacrifice the faster convergence for the algorithm that does not need the partial derivatives evaluation and resembles the secant method [1].

This approach is known as quasi-Newton method and its numerous variants are described in Numerical Optimization [4].

Let \( B \) denote the approximation for the Jacobian matrix \( J_{x}[x^{(0)}] \). The idea of quasi-Newton methods is to base the matrix \( B \) on the Hessian approximation of second-order partial derivatives built up from the gradient values from some previous iteration steps.

**Definition 2.**

```python
def jacobi_iteration(0, x0, k, tol):
    err, i = tol+1, 0
    while err > tol and i < k:
        X1 = G(X0)
        err = norm(X1 - X0)
        i += 1
        X0 = X1
    return X1
```

**Definition 3.**

```python
def F(X):
    return mat([[X[0, 0] ** 4 - 6 * X[0, 0] ** 2 + X[1, 0] ** 2 + X[0, 0], X[1, 0]] ** 4 + 1,
                 4 * X[0, 0] ** 3 + 3 * X[1, 0] - 4 * X[0, 0] ** 2 + X[1, 0] ** 3 + X[1, 0]])

def JF(X):
    d1 = 4 * X[0, 0] ** 3 - 12 * X[0, 0] ** 2 + X[1, 0] ** 2 + 1
    d2 = -12 * X[0, 0] ** 2 + 2 * X[1, 0] + 4 * X[1, 0] ** 3
    return mat([[d1, d2], [-d2, d1]])
```

The methods used by most numerical packages are the Broyden—Fletcher—Goldfarb—Shanno (BFGS) updates and the limited memory L-BFGS method for the large systems of equations. One step of the quasi-Newton method consists of: (i) solving the system \( B \Delta x = -F(x^{(r)}) \), (ii) setting \( x^{(r+1)} = x^{(r)} + \Delta x^{(r)} \), and (iii) computing \( B_{r+1} \) for the next iteration step.

We implement here the well-known Broyden method, available in function `broyden`. The Broyden method takes \( B_{r+1} \) to be the closest matrix to matrix \( B_{r} \), which satisfies the secant condition. [See Definition 3]

The initial matrix \( B_{0} \) passed as parameter \( B0 \) to the `broyden` function, should approximate the Jacobian matrix \( J_{x}[x^{(0)}] \). In the worst case it can be the identity matrix. Theoretical analysis

---

**Figure 1:** The nonlinear system in Eq. 3 has four solutions, each is colored distinctly. Initial values for both variables in Eq. 3 have been repetitively selected from the area in the plane around the origin of the Cartesian coordinate system to depict the Newton method convergence. Each point on the graph has the color of the solution to which the Newton method has converged, if the method was initialized with point’s coordinates. Positions in the plane representing initial values for which the Newton method has not converged are colored black.
shows that instead of naive implementation of the \( \text{broyden} \) method it is better to directly update the inverse of the Jacobian matrix using the Sherman-Morrison formula. This variation is commonly known as good Broyden formula, implemented in good \( \text{broyden} \) function. [See Definition 4.]

**Variational Methods**
Suppose we search an extreme of a twice continuously differentiable function \( F : \mathbb{R}^n \rightarrow \mathbb{R} \). The necessary condition for a point \( x \) to achieve an extrema is that function’s gradient in \( x \) equals zero. If \( x \) is a stationary point of a function, then a Hessian matrix of second order partial derivatives decides about the type and existence of the extrema. Finding an extrema of a multivariate function \( F \) is executed by solving a nonlinear system of equations. However, it goes in the opposite direction as well. As we did earlier, let \( F \) describe the system we try to solve. We construct a new function \( S(x) = \sum_{i=1}^{n} f_i(x) \), which achieves its global minimum in exactly solutions of the system \( F \).

Therefore almost any method suitable for searching the global minimum of a function of \( n \) variables can be used for solving the nonlinear system of equations. These include general descent algorithms and methods such as gradient, coordinate, and conjugate descent.

**Numerical Continuation**
Numerical continuation is an approach of numerically approximating solutions of a system of parametrized nonlinear equations. As it is often difficult to find a good initial approximation we can introduce an additional parameter. The idea is to choose a simpler related problem, which we know how to solve, and then with additional parameters continuously translate the simpler problem to the nonlinear system of equations. We expect that by continuously changing the problem the solutions will also continuously move, and so by tracing well-known solutions of the simpler problem we will come to desired solutions of the nonlinear system.

The numerical methods for solving ordinary differential equations are used for tracing the solutions of the simpler problem. Usually we use a combination of a predictor-corrector technique by first applying a method for ordinary differential equation with initial condition (e.g. the Euler method) and proceed by computing the solution to the nonlinear system from the result of differential equation with one of the methods discussed earlier. Numerical continuation is detailed in Allgower and Georg’s Numerical Continuation Methods [5].

**Conclusion**
Described techniques are part of a fundamental suite of useful algorithms widely applicable in numerical modeling and often used as building blocks in many computer science and engineering approaches. Numerical models can take many forms, including static and dynamic systems, differential equations, statistical or game theoretic models. It is common for different types of models to overlap and involve a variety of heterogeneous structures. Although one may recognize studying numerical methods as tedious work, their wide applicability and valuable insights on the modeled system always prevail.

**References**

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EDSA Shangri-La Hotel
Mandaluyong City, Philippines
December 11–13, 2012

**International Conference on Connected Vehicles and Expo (ICCVE)**
China National Convention Center
Beijing, China
December 12–16, 2012

**10th International Conference on Frontiers of Information Technology**
Serena Hotel
Islamabad, Pakistan
December 17–19, 2012

**2012 International Conference on Computerized Healthcare (ICCH 2012)**
Hong Kong, China
December 17–18, 2012

**Third Kuwait Conference on e-Services and e-Systems**
Kuwait University
Kuwait
December 18–20, 2012
[http://www.kcess.org](http://www.kcess.org)

**2012 International Conference on Sociality and Humanities (ICOSH)**
Kuala Lumpur, Malaysia
December 22–23, 2012
[http://www.icosh.org/index.htm](http://www.icosh.org/index.htm)

**2012 International Conference on e-Education, Entertainment and e-Management (ICEEE)**
Yogyakarta, Indonesia
December 22–23, 2012
[http://www.iceee-conf.org](http://www.iceee-conf.org)

**15th International Conference on Computer & Information Technology (ICCIT)**
University of Chittagong
Chittagong, Bangladesh
December 22–24, 2012

**International Conference on Technical and Executive Innovation in Computing and Communication (TEICC)**
University of Chittagong
Bikaner, Rajasthan, India
December 27–28, 2012
[http://www.teicc.in/index.html](http://www.teicc.in/index.html)

**Fourth International Conference on Intelligent Human Computer Interaction (IHCI)**
IIT Kharagpur
Kharagpur, India
December 27–29, 2012
[http://ihci2012.iitkgp.ac.in](http://ihci2012.iitkgp.ac.in)

**Eighth SIMSR Global Marketing Conference on Marketing Metamorphosis**
Somasaiya Institute of Management Studies & Research
Mumbai, India
January 4–5, 2013
[http://simsr.somasaiya.edu/simsr/sgmnc/index.html](http://simsr.somasaiya.edu/simsr/sgmnc/index.html)

**International Congress on Social Sciences and Business**
The Grand Hotel
Taipei, Taiwan
January 8–10, 2013

**Third Annual Symposium on Computing for Development (DEV 2013)**
Hotel Chancery Pavilion
Bangalore, India
January 11–12, 2013

**The 10th Annual IEEE Consumer Communications & Networking Conference (CCNC 2013)**
Las Vegas, NV
January 11–14, 2013
[http://www.ieee-ccnc.org](http://www.ieee-ccnc.org)

**2013 International Conference on Information and Education Technology (ICIET)**
Sheraton Hotel
Bruxelles, Belgium
January 12–13, 2013
[http://www.iciet.org/index.htm](http://www.iciet.org/index.htm)

**IEEE EMBS Special Topic Conference on Point-of-Care Healthcare Technologies (PoCHT)**
Sheraton Hotel
Bangalore, India
January 16–18, 2013
[http://pocht.embs.org/2013](http://pocht.embs.org/2013)

Dubai, UAE
January 19–20, 2013
[http://www.ic4e.net](http://www.ic4e.net)

**2013 International Conference on Scientific Research and Studies (ICSRS)**
Dubai, UAE
January 19–20, 2013
[http://www.icsrs.org/index.htm](http://www.icsrs.org/index.htm)

**Second International Conference on Government, Law and Culture (ICGLC)**
Dubai, UAE
January 19–20, 2013
[http://www.icglc.org/index.htm](http://www.icglc.org/index.htm)

**2013 International Conference on Innovation and Information Management (ICIM)**
Singapore
January 19–20, 2013
[http://www.icim.org/index.htm](http://www.icim.org/index.htm)

**International Conference on Computing, Management & Telecommunications (COMMANTEL)**
Rex Hotel
Ho Chi Minh City, Vietnam
January 21–24, 2013
[http://commantel.net/2013](http://commantel.net/2013)

**ENTER 2013 e-Tourism Conference**
Congress Innsbruck Convention Centre
Innsbruck, Austria
January 22–25, 2013
[http://www.enter-2013.org](http://www.enter-2013.org)
The 15th International Conference on Advanced Communications Technology (ICACT 2013)
Phoenix Park
Pyeongchang, Korea
January 27–30, 2013
http://www.icact.org/index.asp

International Conference on Computing, Networking & Communications (ICNC)
Hyatt Regency Mission Bay Spa & Marina
San Diego, CA
January 28–31, 2013
http://www.conf-icnc.org/2013

2013 2nd International Conference on Educational and Information Technology (ICEIT 2013)
Hong Kong
February 2–3, 2012
http://www.iceit.org/index.htm

Third International Conference on e-Learning and Distance Learning
Riyadh, Saudi Arabia
February 4–7, 2013
http://eli.elc.edu.sa/2013/en

Information Systems in Southeast-Asia (MCIS)
Le-Meridien Hotel
Kota Kinabalu, Sabah, Malaysia
February 13–16, 2013
http://wwwkal.ums.edu.my/mcis2013/index.html

ICT for Sustainability
ETH, Zurich
Zurich, Switzerland
February 14–16, 2013
http://www.ict4s.org

2013 Fifth International Conference on Computer Research and Development (ICCRD)
Science and Engineering Institute
Ho Chi Minh City, Vietnam
February 23–24, 2013
http://www.iccrd.org/index.htm

2013 Second International Conference on Education and Management Innovation (ICEMI)
Science and Engineering Institute
Rome, Italy
February 24–25, 2013
http://www.icemi.org

2013 Fourth International Conference on Financial Theory and Engineering (ICFTE)
Rome, Italy
February 24–25, 2013
http://www.icfte.org/index.htm

The Second International Conference on e-Technologies and Networks for Development (ICEnd 2013)
Kuala Lumpur, Malaysia
March 4–6, 2013
http://sdiwc.net/conferences/2013/Malaysia2

Human Factors in Computing (CHI) 2013
Paris, France
April 27 – May 2, 2013
http://chi2013.acm.org

ICTD2013
Cape Town, South Africa
December 7–10, 2013
http://ictdconference.org

CONTESTS & EVENTS

DCWEEK 2012
DCWEEK is a weeklong festival in the nation's capital focused on bringing together designer, developers, entrepreneurs, and social innovators of all kinds. It's a series of hundreds of distributed events powered by the community and complemented by core conferences, parties, and projects created by the festival organizers iStrategyLabs and Tech Cocktail. DCWEEK 2011 included more than 10,000 attendees from around the world. DCWEEK is an ample platform to meet new friends, clients, partners, investors and collaborators. This platform is all set to be a launch pad of some great projects, built upon some great ideas that may benefit the U.S, as well as the world. For further details visit http://digitalcapitalweek.org/

IGF 2012
The seventh meeting of the Internet Governance Forum (IGF) was held November 2012 in Baku, Azerbaijan. The proposed theme of the 2012 IGF annual meeting was “Internet Governance for Sustainable Human, Economic...”

FEATURED EVENT

International Conference on Advances in ICT for Emerging Regions (ICTER)
Colombo, Sri Lanka
December 12–15, 2012

Millions of people in developing nations from Asia, Africa, and South America do not currently have access to basic civic amenities and basic healthcare facilities. For this reason, it's high time the computing community started thinking about implementing proper information and communication technologies for the development of the poor, including better governmental and economic policies and better healthcare and business opportunities.

Thus, it's a perfect moment for all of us to show what we can do in order to help developing and emerging economies, and no other platform can be as good as ICTER 2012. The event, organized by IEEE, is being held in Colombo, Sri Lanka. It will cover a broad range of fields from technology to social, ethical, and legal issues. Several keynote addresses by leading experts in the domain of IT will take place as well as a student symposium, which will be held on the 15th of December.

For more information, log on to http://www.icter.org/conference/.

—Arka Bhattacharya
and Social Development.” Every day the Internet is penetrating our lives in more ways than one, bringing forth new ideas and making our lives easier. As the Internet helps promote various viewpoints to a global community, these new trends should be duly discussed and broadly agreed upon before changes are made that can significantly impact our future. IGF is the platform for discussing the global implications of ICT in the world and the trends of its future development. For further details please visit http://www.igf2012.com/

GRANTS, SCHOLARSHIPS & FELLOWSHIPS

Naval Research Enterprise Internship Program
Website: http://nreip.asee.org/
Deadline: January 7, 2013
Eligibility: U.S. citizens who have completed their first year of undergrad or are graduate students.
Benefits: $5,385–$10,750
Explanation: This is a research internship opportunity at one of the 21 U.S. Department of Navy research laboratories. Two hundred undergraduates and 75 graduates are offered a 10-week paid internship.

Department of Energy Computational Science Graduate Fellowship
Website: http://www.krellinst.org/csgf
Deadline: January 8, 2013
Eligibility: U.S. citizens and permanent residents planning study towards a Ph.D. at an accredited U.S. university, and have not yet started their second year of doctoral studies.
Benefits: $36,000 stipend, tuition, and fees for up to four years. An allowance for a computer workstation is added.
Explanation: The Computation Sciences Graduate Fellowship is meant to encourage interdisciplinary work and collaboration in the field of computational science. The fellowship includes a practicum at a Department of Energy laboratory. A conference is held each summer for recipients.

ICTD RESOURCES

Theoretically based on the Schumpeterian notion of socio-economic evolution, which consists of an incessant process of “creative destruction,” Information and Communication Technologies (ICT) for Development (ICT4D) broadly belongs to the school of thought that proposes to use technology for economic, social, cultural, and political development. Historically, ICT4D can be somewhat put into three phases: (i) mid-1950s – late-1990s, when computing technology was...
mostly concentrated in large private sector and government organizations in developing nations; (ii) mid-1990s – late-2000s, when rapid expansion of Internet use in advanced economics brought about higher investments in ICT infrastructure in developing countries, e.g., in telecentres; and (iii) late-2000s onwards, the technology is being increasingly available over the mobile and ubiquitous devices.

While many developing economies have and are adopting ICT4D, there are also rising criticisms over several issues, such as CO2 emissions.

BOOKS, JOURNALS, AND MAGAZINES

ICT4D: Information and Communication Technology for Development (Cambridge Learning)
Tim Unwin, Cambridge University Press (2009)

Description (from Amazon):
ICT4D provides an authoritative account of the use of Information and Communication Technologies (ICTs) in contemporary development practice. It combines theory with practical guidance—including both a conceptual framework for understanding the rapid development of ICT4D. Case studies provide detailed examples of issues and initiatives from a variety of countries and organisations. ICTs are becoming increasingly significant in improving the impacts of development practice. However, ICT4D projects in Africa, Asia and Latin America have not always been as effective as their proponents had hoped. This book explores both the successes and the challenges facing such initiatives, and provides clear recommendations for how they can be developed in more sustainable ways for the benefit of poor people and marginalized communities.

ACM Interactions (“Under Development” column)
http://interactions.acm.org/

NOTEWORTHY BLOGS

Afrigadget
http://www.afrigadget.com/

Ethan Zuckerman
http://ethanzuckerman.com/blog/

Jan Chipchase
http://www.janchipchase.com/

Jonathan Donner
http://jonathandonner.com/blog

Kentaro Toyama
http://ict4djester.org/blog/

MobileActive
http://mobileactive.org/blog

Putting People First
http://www.experientia.com/blog/category/emerging-markets/

White African
http://whiteafrican.com/

USEFUL WEBSITES

Artificial Intelligence for Development (AI-D)
http://ai-d.org/index.html

Governance and Social Development Resource Centre
http://www.gsdrc.org/

HCI4D SIG
http://www.sigchi.org/communities/hci4d

IDEO Human Centered Design Toolkit
http://www.ideo.com/work/human-centered-design-toolkit/

International Development Research Center
http://www.idrc.ca/EN/Pages/default.aspx

ITU Telecommunication Development Sector
http://www.itu.int/ITU-D/

Learn ICT UK
http://www.learn-ict.org.uk/

M4D References on Mendeley
http://www.mendeley.com/groups/817031/m4d-mobile-cellular-phones-for-and-development/

UNDP Asia-Pacific Development Information Programme
ICT4D Case Studies
http://www.apdip.net/resources/case
Why Zip Codes have Connotations

Anatomy of a Winter Break

Poor Things

Puzzle: Visibility

Which number follows in the series 10, 9, 60, 90, 70, 66?

Find the solution at: http://xrds.acm.org/bemusement/2012.cfm

Source: The Visibility Blog by Raul Cristian Aguirre; http://thevisibilityblog.com/2012/06/28/problem-solved/

Submit a Puzzle

Can you do better? Bemusements would like your puzzles and mathematical games [but not Sudoku].

Contact xrds@acm.org to submit yours!
STUDENT MEMBERSHIP APPLICATION

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EDUCATION

Name of School $
Please check one: 1 High School (Pre-college, Secondary) $
College: 2 Freshman (1st yr) $
Sophomore (2nd yr) $
Junior (3rd yr) $
Senior (4th yr) $
Graduate Student: 3 Masters Program $
Doctorate Program $
Postdoctoral Program $
Non-Traditional Student $

Major $
Expected mo./yr of grad $

Age Range: 1 17 & under 2 18-21 3 22-25 4 26-30
5 31-35 6 36-40 7 41-45 8 46-50 9 51-55 10 56-59 11 60+

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I attest that the information given is correct and that I will abide by the ACM Code of Ethics. I understand that my membership is non-transferable.

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