Computing for Global Health

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with
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John Pitman, Sridhar Basavaraju (CDC)
Bright Mulenga and team (ZNBTS)

Computing for Global Health

- Health problems are exacerbated by:
  - Ignorance of health risks
  - Lack of timely information on prevention and treatment
  - Scarcity of resources including medical supplies
  - Limited medical expertise
  - …

These problems are more acute in developing regions

Computing for Global Health

- Many attempts to use the internet and other communication devices, e.g.,
  - Tele-medicine
  - Internet-based screening
  - PDA-based guides for diagnosis
  - Disease tracking
  - Etc.

Varying success. Often not sustained.

This talk is about our experience over the past 1.5 years.

John Pitman

- Africa Correspondent for VOA
- Health Officer, CDC

Met at John Howell Park, Atlanta.

Works in the Blood Safety division of the Global AIDS Program (GAP).

Blood Safety

- Major problem
- Especially in developing countries
- Blood supply does not match demand
- Blood could be infected

- Problem: how to monitor and improve blood safety?

Big Problem

- In 2002, transfusions were identified as the cause of 5-10% of HIV infections in developing countries.[1]

[1] WHO. Blood Safety and Clinical Technology Progress 2000-2001, 2002.

President's Emergency Plan For AIDS Relief

- PEPFAR supports Ministries of Health and/or National Blood Transfusion Services in 14 countries:

Botswana	**Kenya**	**South Africa**
Cote d'Ivoire	**Mozambique**	**Tanzania**
Ethiopia	**Namibia**	**Uganda**
Guyana	**Nigeria**	**Zambia**
Haiti	**Rwanda**	

- 5 Billion for 5 years. Renewed last year for 5 more.

PEPFAR blood safety monitoring

- Countries submit quarterly reports on about 80 indicators aggregated nationally. CDC uses these reports to assess progress and plan ahead.
- Till 2007, the reports were on paper
- Then moved to an Excel spreadsheet
- Aggregation done manually

Spreadsheet weaknesses

- Difficulty in tracking versions of multiple files as new data were entered and updated by different users
- Countries' inability to quickly modify, clean or correct a data set after a file was submitted to CDC
- Transcription and other errors as multiple versions of the spreadsheet were merged prior to submission.
- PEPFAR requires quarterly reports from each country, but blood is collected, tested and utilized continuously. So, the spreadsheet could be idle for months at a time.

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Enter Georgia Tech

- Appeared to be a project for a computer science major
- Create a web-based monitoring system for blood?

- But (as an academic),
  - Is there any research to be done here?
  - My research areas --- algorithms, randomness and geometry --- don't seem relevant.

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Computing for Good/Social Change

- In 2008, the college of computing started C4G, to identify and solve real-life problems that would improve someone's quality of life using ideas from computing.
- A course was conducted last spring.
- 17 students worked on 7 projects
- A blood safety tool was one of them
- (Others: homeless shelter occupancy, low-income internet, kiosk for TRC Liberia, low-power wireless networks, avian influenza tracking)

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Blood safety web tool team

- Bola Osuntogun, Stephen Thomas (PhD students)
- Santosh Vempala

- John Pitman, Sridhar Basavaraju (CDC)

- Joseph Mulenga, Bright Mulenga, David Chama, Chitindi Sakalo, Alex Chikwese, Dia Kumwenda, Zindaba Tembo (Zambia NBTS)

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Web tool features

- A reliable, authoritative source of reported data. (No more wondering which file is most accurate.)
- Data is continuously available throughout the reporting period allowing immediate modifications. (No files "in transit" or lost via email.)
- Automated, real-time aggregation of reported data from multiple sources with less risk of transcription errors.
- Access is ubiquitous and available on all modern computing platforms. Users only need familiarity with a web browser.
- Updates and enhancements are easily managed and deployed.

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But is the internet available?

- **Network compatibility.** The system must support access through low bandwidth, dial-up connections.
- **Contextual interface**. The system must provide a user experience appropriate for blood safety staff who lack high-level IT training.
- **Security**. The system must provide appropriate security and access control for aggregated health information.
- **Flexible and adaptable.** The system must be easy to manage, adapt, and expand.

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Evaluation

- Pre-trial survey by email
- 2-week trip to Zambia
- Conducted user studies
- Visited Blood centers in Lusaka (Capital), Kabwe (Central province) and Kitwe (Copperbelt province)
- Over the telephone with Dar-es-Salaam, Tanzania.

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Location

Zambia
Population: 12 million
HIV rate: 17%

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Location

Evaluation: Pre-trial questions

- 1 You have forgotten your password and need to log into the web-based system. How hard or easy do you expect to find this task?
- 2a You are only responsible for reporting some of the data, while other users report the remaining data. You need to enter the data for which you are responsible without disturbing the other data. How hard or easy do you expect to find this task?
- 2b At the close of a deadline, you have only partial information to report. How hard or easy do you expect to find this task?
- 3 Previously entered data is wrong, and you must provide the correct information. How hard or easy do you expect to find this task?
- 4 What are some of the advantages you expect from a web-based system compared to the old spreadsheet tool?
- 5 What are some of the disadvantages you expect from a web-based system compared to the old spreadsheet tool?

Evaluation: Task list

- 1 Your username is country/province@blood-safety.org and the password is the word "password". Use the system to change the password to "country/province".
- 2a Enter the regional information for the current quarter.
- 2b You are entering data for the current quarter for your country/province. You only have data for all the nonnumeric fields. Enter and save this part of the data.
- 3 There is an error in the HIV prevalence field. Please correct it.
- 4 Export the country/province data to an XML file and view the data using Excel.

Lusaka Blood Center

Evaluation at Kitwe Blood Center

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Younger participants

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Kitwe staff

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Kabwe Blood Center

Kabwe Staff

Back in Lusaka

Qualitative findings

- **Utility and maintenance**. Timely reporting; quicker and less tedious; more cost-effective; reduces errors, easier to correct errors; more user-friendly; easier to share data.
- **Functionality**. Data managers felt that a real-time aggregate picture would enhance their ability to manage blood. Asked for historical trends and comparisons of data from different regions.
- **Network constraints**. Would pages load too slowly? Would the system be able to handle connectivity going up and down?

Network Availability

- Zambia has no fiber leaving the country, i.e., all communication is via Satellite.
  - Dialup, wireless+dedicated tower had comparable response times

- Measurements
  - Bandwidth:
    - Lusaka -> NY 12-57 kb/s
    - NY -> Lusaka 88-116 kb/s
  - Latency: 5.1 – 6.8 sec. round trip

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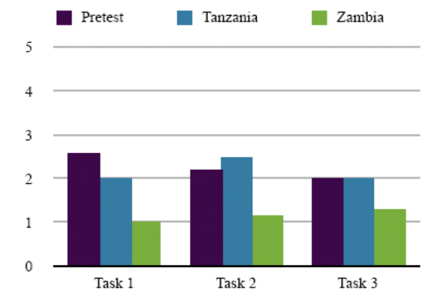
Evaluation: Results



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Blood Safety Indicator System

- http://www.blood-safety.org

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http://www.blood-safety.org

- Allows local Data Flow constraints
- Flexible, end-user customizable design
- User interface based on unobtrusive enhancement

- To appear in ICTD 2009.

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Blood Safety Indicator System

- Started deployment Jan 1, 2009 in all 14 countries.
- Met with the WHO on Nov 17th at their request after they saw our presentation at the AABB conference in Montreal. The WHO will use the tool for annual worldwide blood safety reporting.

A Broader Problem?

- Monitoring/Reporting is necessary, but is that all we need to manage blood effectively?

V2V

- Blood supply and usage management is essential to deliver blood efficiently and fairly.

Goals

- Monitor blood collection, distribution and usage
- Predict blood unit needs
- Produce an optimal way of distributing blood to different blood banks
- Deliver blood efficiently

1: A hospital in Kitwe calls you requesting 50 units of blood. What factors do you use to decide whether they get those units and when they get those blood units?

- Important Factors
  - Has regional blood bank been contacted
  - Blood levels in the regional blood bank
  - Nationwide stock level
  - Reason why supply is low
- Other factors arranged in order of importance
  - Blood consumption pattern – monthly
  - Date of last request
  - Blood utilization reports
  - Current stock levels at hospital by type and expiry date

  - Category of hospital (acute bed capacity)
  - Storage, testing and distribution capacity
  - How effective is the cold chain

  - Staffing level
  - Transportation availability
  - Authenticity of request

2: A driver comes from the Central Province blood bank. What are the possible things he may pick up or deliver?

- Blood units
- Blood bags
- Test kits,pipettes, test tubes
- Laboratory consumables
- Equipment
- Educational material, posters, forms
- Reports

3: A driver comes from a hospital in Lusaka. What are the possible things he may pick up or deliver?

- Blood units, components
- Laboratory consumables (blood grouping sera, blood administration sets etc.)
- Posters, forms
- Reports
- Non-NBTS resources

4: You suspect that Northwest province is requesting too many blood units, how do you confirm this?

- Utilization/requests from the hospital
- Disaster/emergency
- Data on forms used to issue blood to the province
- Data on blood collected at the province
- Data on blood distributed by the province
- Blood utilization reports of the province
- Usage pattern
- Estimate need based on number of transfusion outlets
- Performance in blood collection
- Number of blood units expiring
- Stock levels

5:You are preparing to allocate blood supplies to be transported to the different hospitals for the next month. What information do you use to decide which hospital gets what blood type and how many units they obtain?

- Population and hospital capacities
- Storage capacities
- Demand
- Distance and transportation challenges
- Usage pattern
- Stock level
- Type of blood (not an issue in Zambia)
- Uniform distribution, blood types are distributed as evenly as possible
- Season of the year
- Disease prevalence (malaria) by region
- Pattern of blood types in the regional population (not in Zambia)

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6: You receive a request from Southern province requesting 50 units of blood, and the same request from Luapula province? You only have 75 units to supply. How do you determine how much each region gets?

- Conditions/usage to determine emergencies
- Transportation difficulty
- Available donors in the province
- Consumption pattern
- Transfusion outlets
- Maternal and infant mortality rate (medical history)

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7: You obtain a report from a hospital that a certain unit of blood was defective, how do you determine the cause and origin of the defect?

- Type of defect, conduct inspection if necessary
- Track unique number backwards
- Track test sample
- Retest the sample and compare results
- Test for bacterial contamination and clotting
- Dispatch and reception notes
- Blood release details
- Stock and batch number
- Examine stocks with same batch number for defect
- Transportation method used
- Cold chain equipment
- Expiry date
- Condition of blood bag

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V2V basics (Bola Osuntogun)

The efficient use of blood has three components:

- Monitoring
- Prediction
- Allocation

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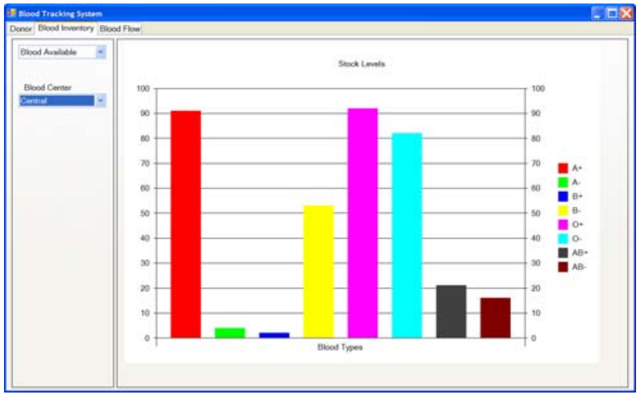
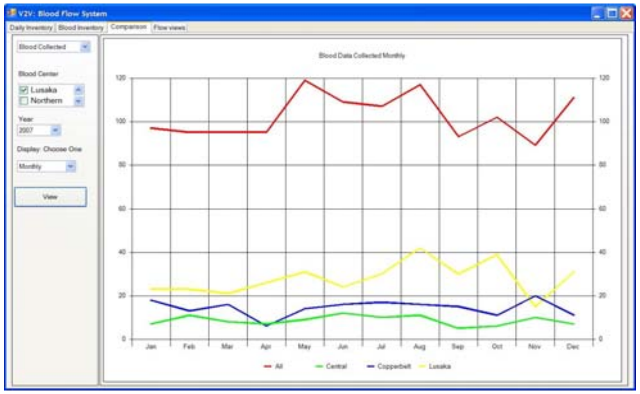
Monitoring

- Monitor the collection and usage patterns of blood units at different blood centers and transfusion outlets
  - Inventory views based on data at individual locations
  - Flow views based on flow of blood from one location to another

Sample Inventory View



Sample Comparison View



Flow Views

- Track a single blood unit from collection to the location of transfusion or discard
- Track a set or range of blood units (e.g., all blood units collected on the same day at one center) from collection to transfusion or discard.
- Flow of blood units to and from a location (regional center or healthcare facility) for a chosen time period
- Flow from and to a location
- Flow from blood centers to healthcare facilities

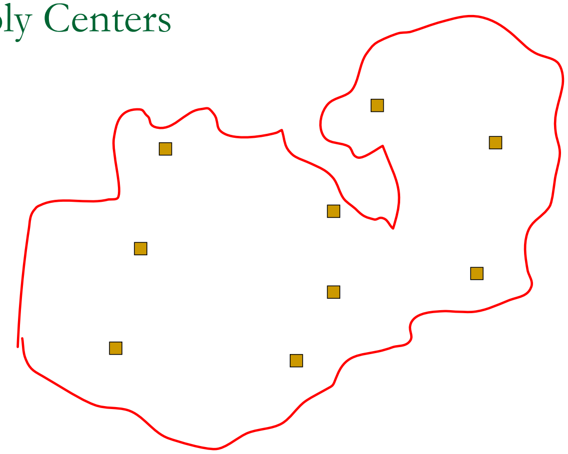
Prediction

- Based on a probabilistic model of individual units of blood
- To be validated soon on real data

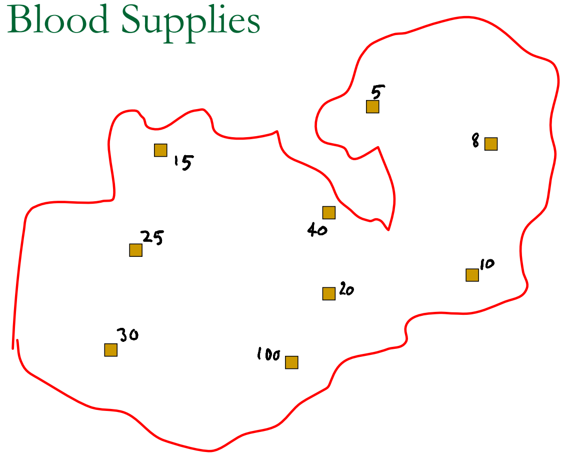
Allocation

- Find a flow assignment of blood from collection centers to transfusion outlets with the goals of fair and efficient utilization.

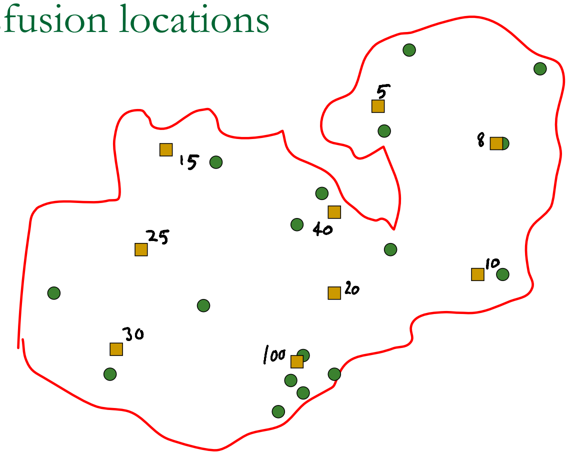
Supply Centers



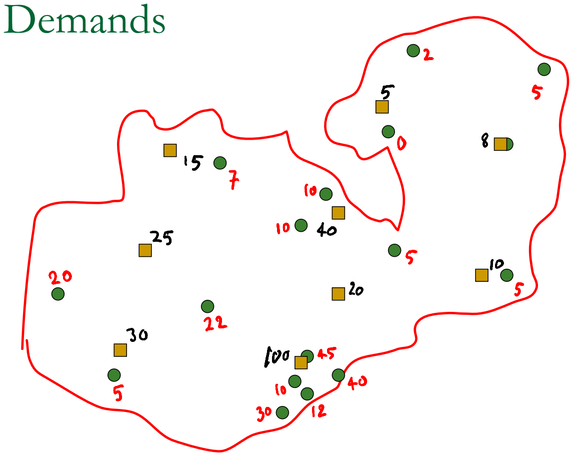
With Blood Supplies



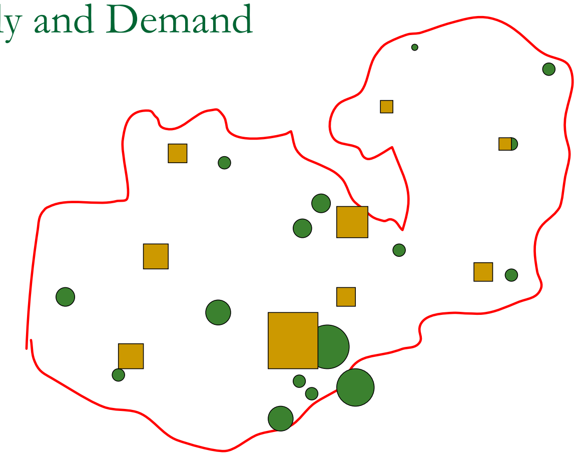
Transfusion locations



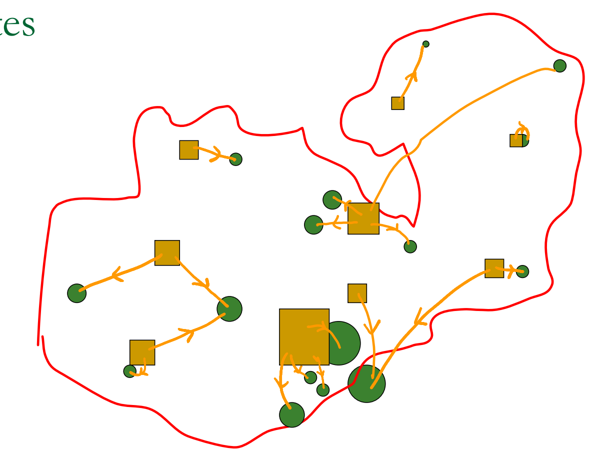
With Demands



Supply and Demand



Routes



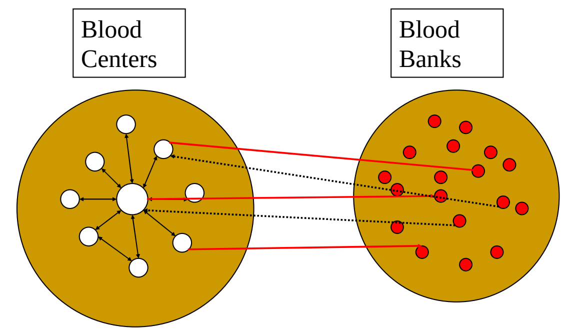
A Matching Network

- Blood supply: units with time limits
- Blood demand: units with time limits
- Routes with delays and costs

Find a matching between supply and demand centers that
- satisfies as much demand as possible while staying within budget

  or
- Minimizes cost while utilizing all the supply (or satisfying all the demand)

Solution: Maintain an optimal matching



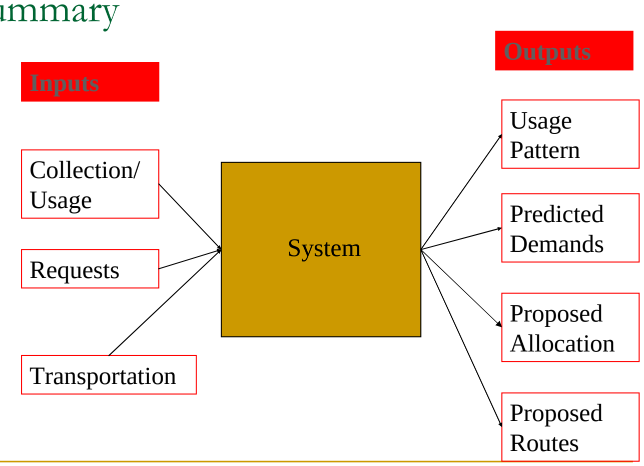
Algorithm

- Build space-time graph
- A copy of each center for each day (or smaller time unit)
- Edges representing routes. Edge

  (c,i) → (d,j)

  if blood can be delivered from c to d in at most j-i time units
- Find minimum cost (delay) perfect matching
- Update graph

Summary



Computing for Developing Regions

- A rewarding experience
- Resource scarcity leads to important constraints on the solution space; new ideas are needed.
- Often leads to difficult and fundamental scientific problems, e.g.,
    1. How to efficiently choose a fair allocation of limited resources (of blood) ?
    2. What kind of internet would be an *empathic* network? How to enable it?
    3. How to design a user interface for web-based monitoring?