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Data Simplification and Data Visualization for Cognitive Support in clinical care

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Objectives

- The data challenge in clinical care and medical research
- Designing cognitive support to meet this challenge
- Visualization methods for cognitive support

Growth in electronic data is outstripping storage

- General storage
  - By 2011, the amount of digital information in existence will exceed the total storage space available by almost 50 percent, according to analyst IDC.[1]
- Bioinformatics
  - Genbank doubling every 18 months.[2]
- One drop of blood can generate
  - 60 gigabytes of unstructured data for proteomic studies[3]
- 2 hours in the ICU can generate ~2 GB of data

Future trends

- $500 personal genome expected in 3 years[4]
- Federal Government has funded $564 million[5] to fund state Health Information Exchanges, increasing the amount of information to clinicians
- Does increased information lead to better care?

Recent report from National Research Council

- Computational Technology for Effective Healthcare[6]
  - Immediate Steps and Strategic Directions
- An Overarching Research Grand Challenge: Patient-Centered Cognitive Support
  - The clinician interacts with models and abstractions of the patient that place the raw data into context and synthesize them with medical knowledge in ways that make clinical sense for that patient.
  - Raw data is still available, but they are not the direct focus of the clinician.

Poll

- In the current clinical environment, what level of information do the clinicians have about the patients at their fingertips:
  - Too much information
  - Just the right amount of information
  - Not enough information

Data simplification

- One solution is to reduce the quantity of data that must be digested to the provider, so informed decisions can be made.
- The data does not disappear but becomes molded into paradigms that the health care system can process.

Information Theory

- Branch of applied mathematics
  - To find fundamental limits on compressing, storing and communicating data
- Data simplification
  - Applies the medical knowledge and domain expertise to reduce the complexity of the data to aid support

Cognitive Support vs Decision Support

- Decision Support in electronic health records[7]
  – active knowledge systems which use two or more items of patient data to generate case-specific advice
- Cognitive Support in clinical care
  – Patient data integrated to provide clinicians specific information to aid decision making abilities
- Difference is no advice given in Cognitive Support

People and Organizational Issues

- People and Organizational Issues[8]
  - To apply the knowledge of human behaviors toward the use of information technology within a health care environment.
  - To effectively describe the benefits and impacts of information technology before paradigm shifts fully occur.
  - To incorporate organizational change management and human concerns into information technology projects.
  - To distinguish between the human and technology issues when system successes or failures occur

Human Factors

- Human Factors Engineering
  - The application of this understanding to the design, development and deployment of systems and services
- Application requires skills of both disciplines and appreciation of limitations

DARPA Virtual Soldier Project

- Defense Advanced Research Projects Agency (DARPA) funded a larger interdisciplinary project called the Virtual Soldier Project (VSP)
- > 15 senior scientists across industry, academia, and governmental labs

History of Penetrating Missiles Mortality

- Mortality of penetrating injuries
  - Siege of Troy 92%
  - Vietnam 71%
- Hospital Mortality
  - 28% in American Civil War
  - 3-14 % in Vietnam

DARPA Virtual Soldier Project

- Penetrating wounds to the thorax and its organs are a major contributor to injury and mortality in the combat setting.
- The purpose of this proposed project is to transform the way we view, study, and interact with information about the human body and its complex and interrelated systems, and in doing so create an applied system that will revolutionize medical care to the soldier.

DARPA Virtual Soldier Project high-level overview

- Computer simulations of physiological responses
- Statistical analysis of physiological signals from surrogate models
- Ontological representation of normal and abnormal anatomy
- Morphometric analysis of CT scans pre and post injury
- Data integration across multiple modalities

DARPA Virtual Soldier Project Roadblocks

- Roadblocks
  - All collaborators were forbidden from using the term model
    - Everyone had a different definition of model
  - Time zones and scheduling necessary meetings
  - Multiple ways of reaching the same results were pursued leading to confusion at times

One Goal of the DARPA Virtual Soldier Project

- Increase the knowledge the Field Medic has during the process of triage
  - Using state of the art modeling and statistics
  - Reduce the complexity of variables to allow rapid assessment of casualty

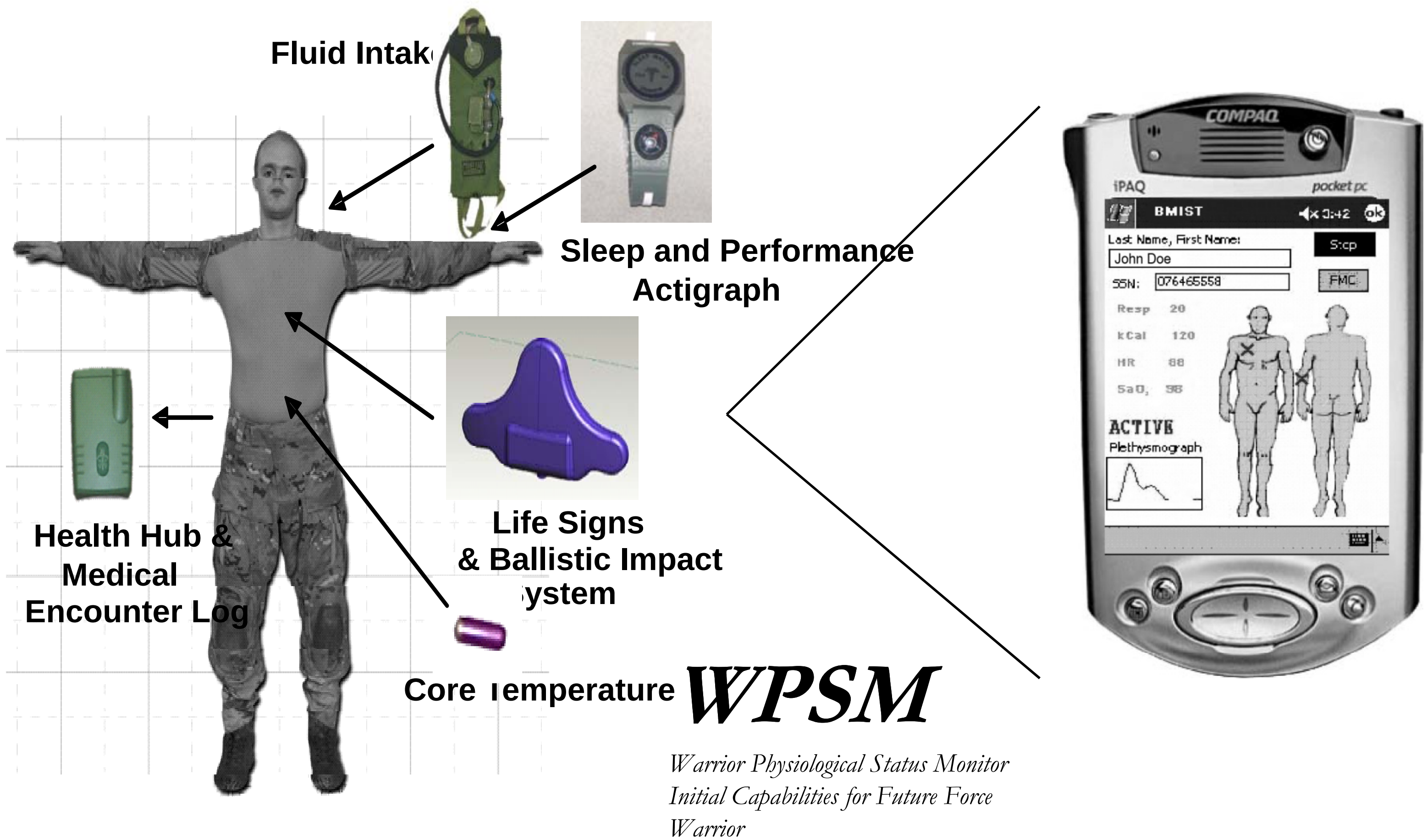
High Level Overview of the DARPA Virtual Soldier Project

- Prior to Deployment into the field:
  - Collect over 12 baseline physiological variable for the individual
  - Obtain cardiac gated Computed Tomography (CT)
  - Create a “Holomer”
    - A integration of image and physiological data
    - Stored on the Personal Information Carrier (PIC) and elsewhere

High Level Overview of the DARPA Virtual Soldier Project
(part 2)

- Post-injury
  - The Highly Integrated Physiological (HIP) computer models are used to model cardiac injury
    - Introduction of few hundred variables and coefficients
  - Kalman Filters are used to process the physiological signals of the injured heart
    - Produces a few outputs
    - Reports forecasts with associated statistical uncertainties
  - Examine blood values to assist modeling and triage

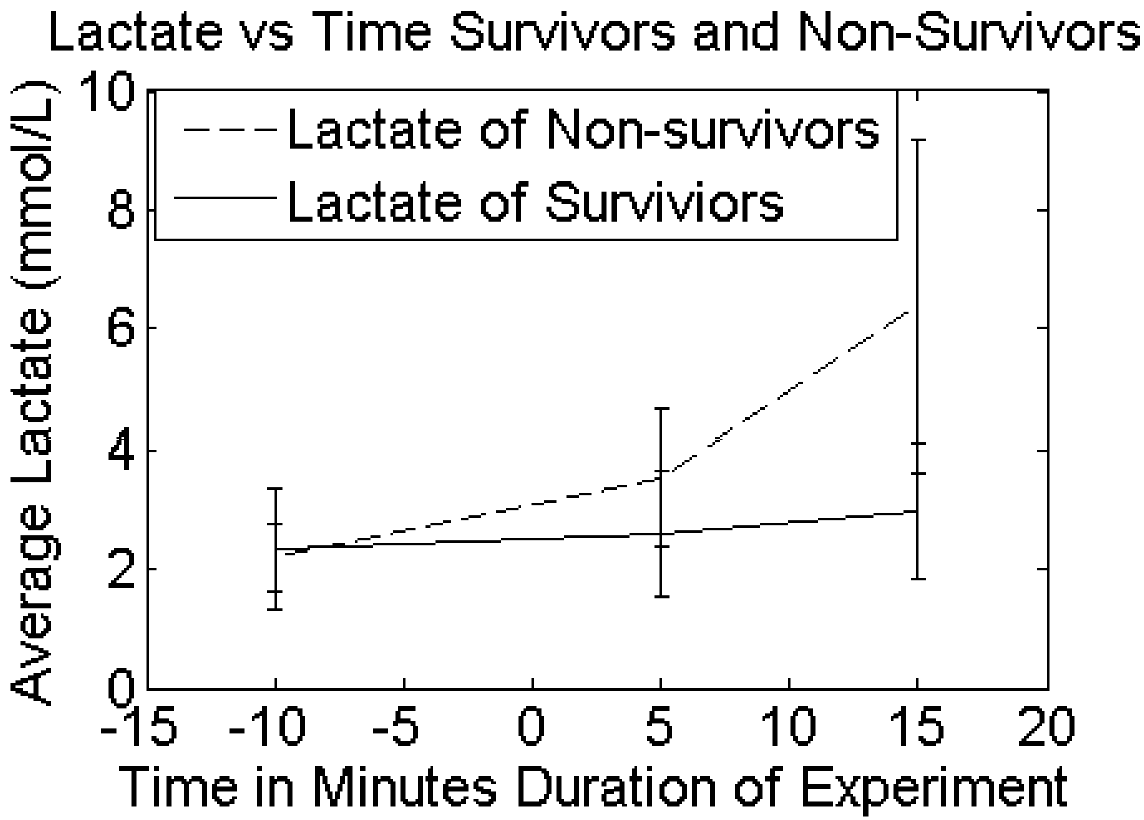
WPSM IC Sensor Interfaces



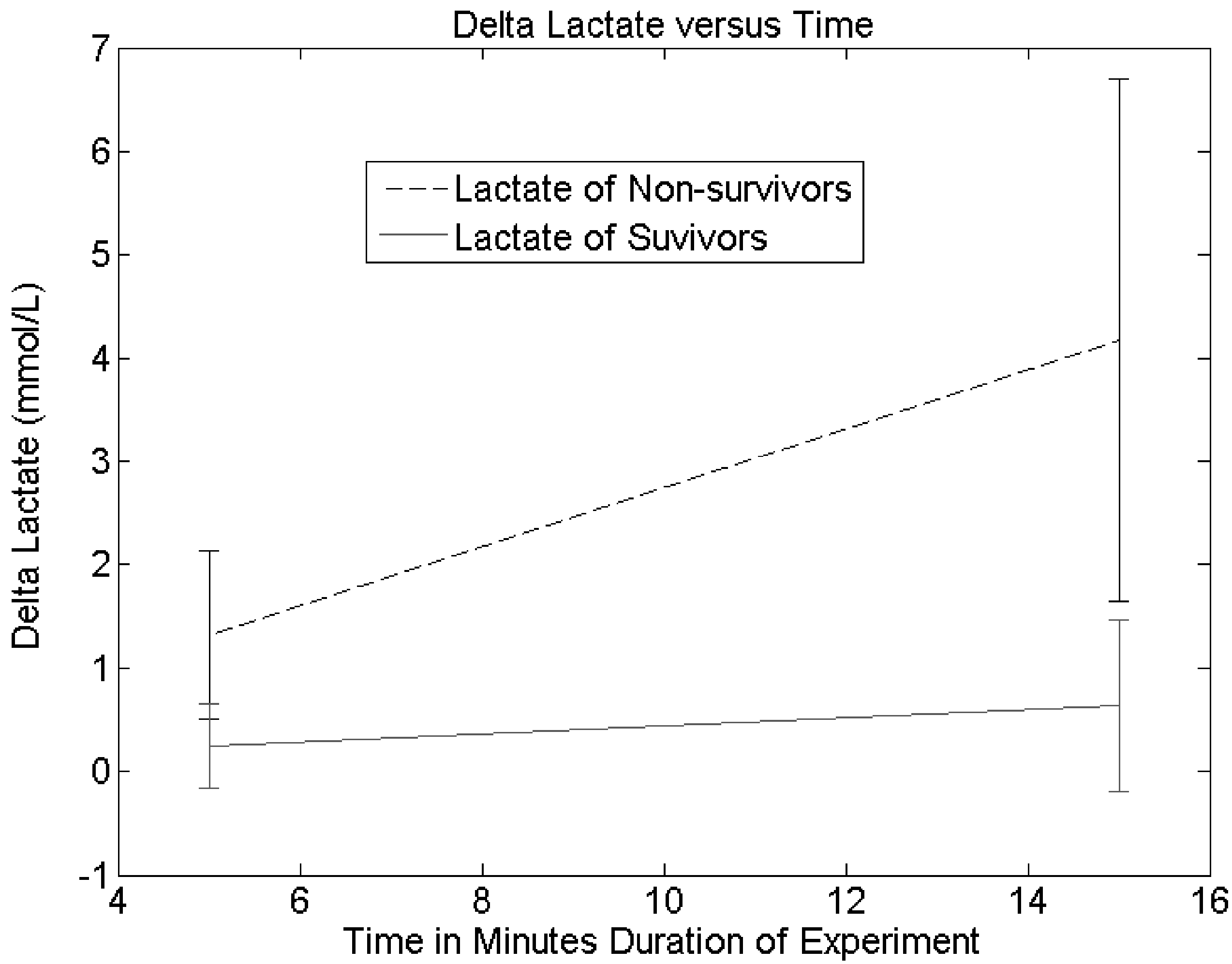
Experiment

- Complex protocol for each test subject is followed a total of 26 subjects
- Pertinent Highlights for Data Analysis
  - Blood values collected before experiment, and at 5, 15, 30, 60, 90 and 120 minutes of the experiments
  - Experiment begins with a penetrating wound to the heart
- Experiments lasts 120 minutes
- Subjects that had blood exsanguination with in 10 minutes where not included in the study
- Result Grouped into two groups compared
  - Subjects that lived for the full 120 minutes
  - Subjects that died between 10 and 120 minutes
- Animal experiments conducted at US Army Institute for Surgical Research, data shared collaboratively across collaborators

Lactate vs Time.



Delta lactate versus time. Solid Line Survivors, Dashed Line Non-survivors.



Brief overview of Triage

- One of the underlying principles “Triage establishes the order of treatment, not whether treatment is given”
- Four priority classifications of the casualty
  - Immediate
  - Delayed
  - Minimal
  - Expectant

Definitions

- Immediate – demand immediate treatment to save life
- Delayed – less risk of loss of life or limb
- Minimal – casualties might be self treated
- Expectant – only used if resources are limited, so critically injured that only complicated treatment can improve life expectancy

Classification of MEDEVAC

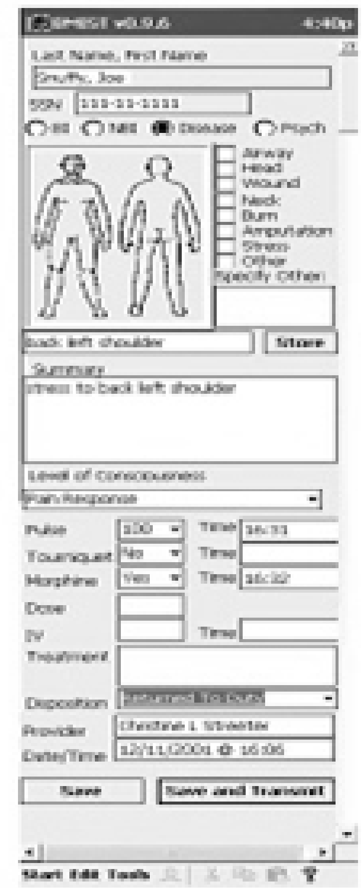
- Medical Evacuation (MEDEVAC) priority
  - Urgent
    - Casualties whose status cannot be controlled and have the greatest opportunity for survival
  - Urgent – Surgical
    - Casualties who need far forward surgical intervention to stabilize
  - Priority
    - Casualties are not stable and at risk of trauma-related complications
  - Routine
    - Casualties can be controlled
  - Convenience
    - Evacuated for convenience, not medical necessity

MEDEVAC

- Larger question the medic is solving
- How do I transport casualty?
  - Factors influencing decision
    - Situational awareness of environment
    - Mission objectives
    - Distance to Far Forward Field hospital
- Reality
  - No computer decision support algorithm possible to include all of the above information
- Cognitive support of how long does the casualty have to live
  - Aids in helping to select transportation methods
  - Assists in triaging
- Decision authority resides in the medic

Compaq IPAQ handheld

- Battlefield Medical Information System Tactical (BMIST)
  - Software deployed world wide
  - Interface with the Personal Information Carrier (PIC)
  - Capture data from encounter with field medic
- Challenges
  - Small screen
  - Modest Computing Power



Challenge of Presenting Data

- Too much data!
- 12 baseline variables (wave forms)
- 300 output variables from the HIP models
- CT images
- Physiological Measurement on Battlefield
- Forecasts and statistical uncertainties

First Possible View

- Small viewer of CT data to see anatomy of soldier
- While helpful further in medical treatment, limited application in the field
- Field Medic will need further training to interpret CT
- Currently only pre-injury CT available
- Future availability of battle field CT scanner

Second Possible View

- Pressure tracing display output from the HIP models
- Models are information rich
- May aid in projecting loss of blood and changes to physiology
- Field Medic will need further training to fully understand all 300 variables
- Too much information for direct field use

Third Possible View

- Simple Text screen with vital signs and statistical predictions
- Allow Medic to decide the ultimate priority of casualty
- Attempts to diagnose and forecast time to death
- Most triage protocols do not include statistical uncertainty. Ours may do so.
- Attempted to highlight HR and BP of current triage protocols

Fourth Possible View

- Simple color coded graph of status
- Allow a field medic an instant snap shot of a casualty
- Information provided in the screen will not help distinguish between Urgent and Urgent-Surgical due to high level abstraction
- Limited information to help decide between Immediate or Expectant

Fifth View

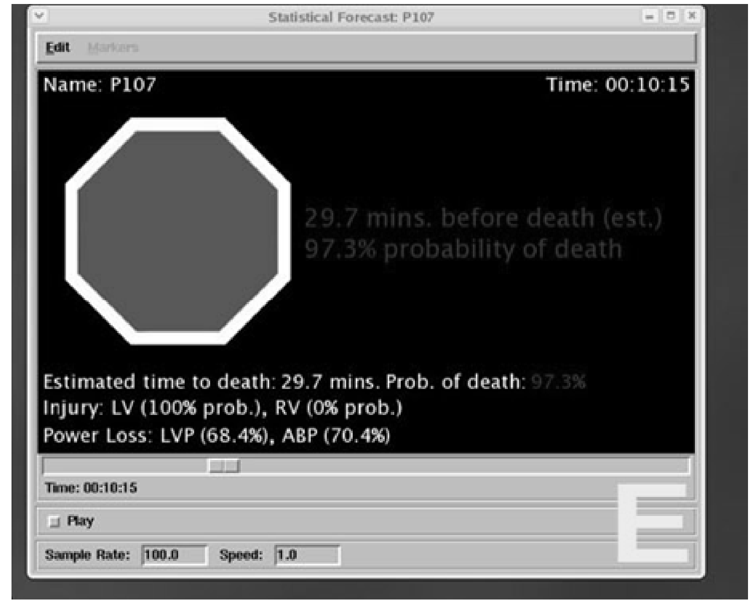
- Text output of the Warfighter Physiological Status Monitoring (WPSM)
- Allowing medic direct access to measurements
- Allows location of wound to be entered into the handheld
- Requires additional processing of data from the medic
- No long term outcome information

Final View : MEDEVAC

Final proposed field Medic Display

The stop sign is either a green circle, yellow triangle, or red stop sign.

Additional information about Estimated time to death is provided for further inspection



Two independent signals could be used to create the stop sign, lactate and bp algorithm.

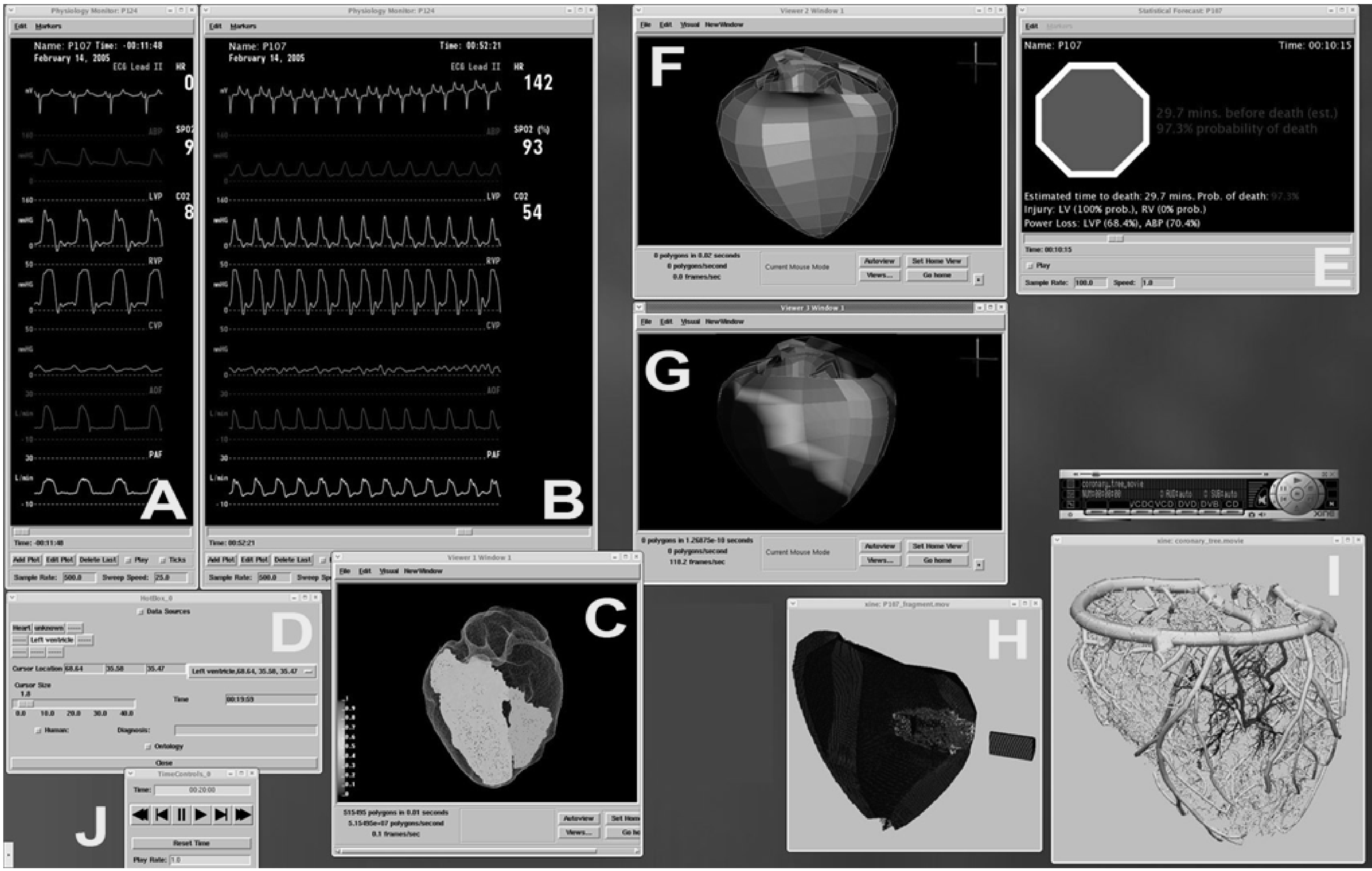
Key goals:

1. The human still makes triage decisions
2. Provide sufficient information for rapid assessment
3. Provide additional information for further refinement of decisions

Poll

- As demonstrated, new information can change how clinicians think and work. When presented with new information (a new lab test, or new procedure) about a clinical or research scenario do you tend to:
  - Ignore the new data
  - Process it and continue traditional work flow
  - Spend hours to understand the implication of the new information and change workflow
  - It depends

Final Physician Display



Visualization methods for : MEDEVAC

- Used existing paradigms of green circle, yellow triangle, and red octagon to visualize high level data
- Future challenges in making explicit uncertainty that is currently excluded in protocols
- Not all data is relevant to critical decision making thoughts

Limitations of existing experiment

- As this project was a prototype
  - No formal evaluation of display was budgeted
- Physician display of data model also needs additional collaboration and refinement
- Data models of diseases and physiological states are challenging and required collaboration across multiple disciplines

Conclusions/Implications

- The implicit uncertainty of triage will become explicit in future triage protocols
- Additional training to incorporate new knowledge into the decision tree of the medic is necessary
- Input from physicians, medics, and usability specialists will need to be consulted for ultimate interface, which may be one or more screens.

Conclusions

- Transforming data into knowledgeable information to guide decision making is a challenge
  - As interfaces are designed, specific clinical questions need to be addressed
  - Increase access to data is not the solution
- Designing cognitive support to meet this challenge
  - Must have interviews and dialogues with all vested parties to understand clinical domain and key clinical questions
- Visualization methods for cognitive support
  - Reuse existing paradigms to increase ease of use

DARPA Collaborators

- Partnering Labs and Investigators
  - Brian Athey, University of Michigan
  - Gerry Moses and Tommy Morris, Telemedicine and Advanced Technology Research Center (TATRC)
  - Chris Johnson, University of Utah
  - Andrew McCulloch, UC- San Diego
  - James Bassingthwaighte and Cornelius Rosse, University of Washington
  - Richard Ward, Oak Ridge National Laboratory
  - Henry Kelly, Federation of American Scientists
  - Mark Musen, Stanford University
  - Bill Lorensen, General Electric Research
  - Bob Eisler, Mission Research Corp
  - LTC. James Fudge and CPT Eric Ansorge, US Army Institute for Surgical Research
  - Tom Menten, Crowley-Davis Research
  - John Monville, Xtria
  - Peter Hunter, University of Auckland
  - Peter Ratitu, Brigham & Women's Hospital, Harvard University
- Funding
  - This work was supported by a grant from DARPA, executed by the U.S. Army Medical Research and Materiel Command/TATRC Contract # W81XWH-04-0012

Citations

- 1. http://www.scc.com/news/data-centre/digital-universe-outstrips-storage-capability?from=1
- 2. Nucleic Acids Research 2008 36(Database issue):D25-D30; doi:10.1093/nar/gkm929
- 3. http://kr.isilon.com/resources/pdfs/brochures_new/Clustered_Storage_Revolution.pdf
- 4. http://dbmichair.mc.vanderbilt.edu/amia2008/
- 5. http://healthit.hhs.gov/portal/server.pt?open=512&objID=1333&parentname=CommunityPage&parentid=47&mode=2&in_hi_userid=11113&cached=true#
- 6. Computational Technology for Effective Health Care: Immediate Steps and Strategic Directions
- http://www.nap.edu/catalog/12572.html
- 7.Wyatt J, & Spiegelhalter D. (1991). Field trials of medical decision-aids: potential problems and solutions. *Proceedings / the ... Annual Symposium on Computer Application [Sic] in Medical Care. Symposium on Computer Applications in Medical Care.* 3-7.
- 8. https://www.amia.org/working-group/people-organizational-issues
- 9. Boyd AD Wright ZC, Ade AS, Bookstein F, Ogden JC, Meixner W, Athey BD, Morris T, "Challenges in Presenting High Dimensional Data to aid in Triage in the DARPA Virtual Soldier Project" Studies in Health Technology and Informatics, 2004, 111, 68-74.