

BIOGREEN 2010  
March 7-13, 2010 - Cancun, Mexico

# **Challenges in Bio-technologies, Systems and Environments**

Joel Jeffrey, Northern Illinois University, USA

Kayvan Najarian, Virginia Commonwealth University, USA

Keat Teong Lee, University Sains Malaysia, Malaysia

Vladimir Strezov, Macquarie University, Australia

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# Challenges in Bio-technology, Systems and Environment

**Vladimir Strezov**

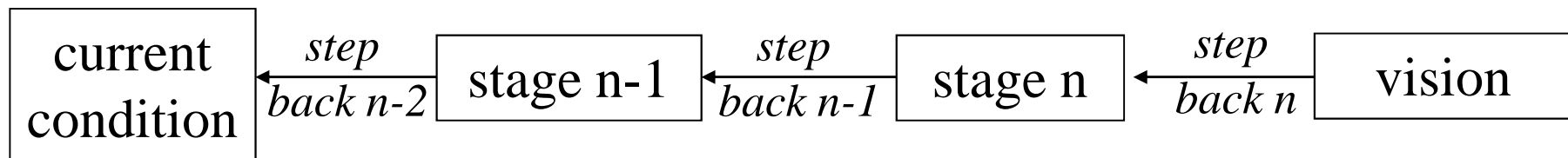
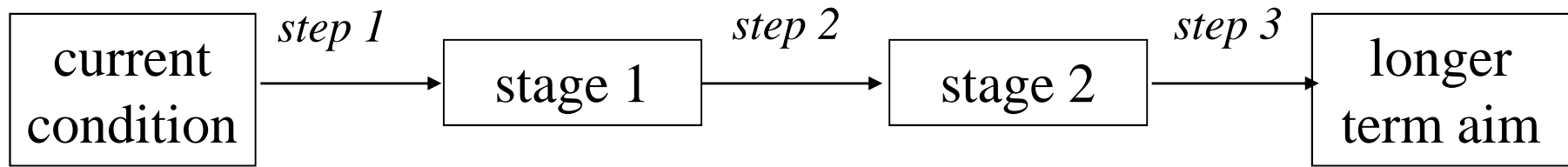
Graduate School of the Environment, Macquarie University, Australia

# Challenges

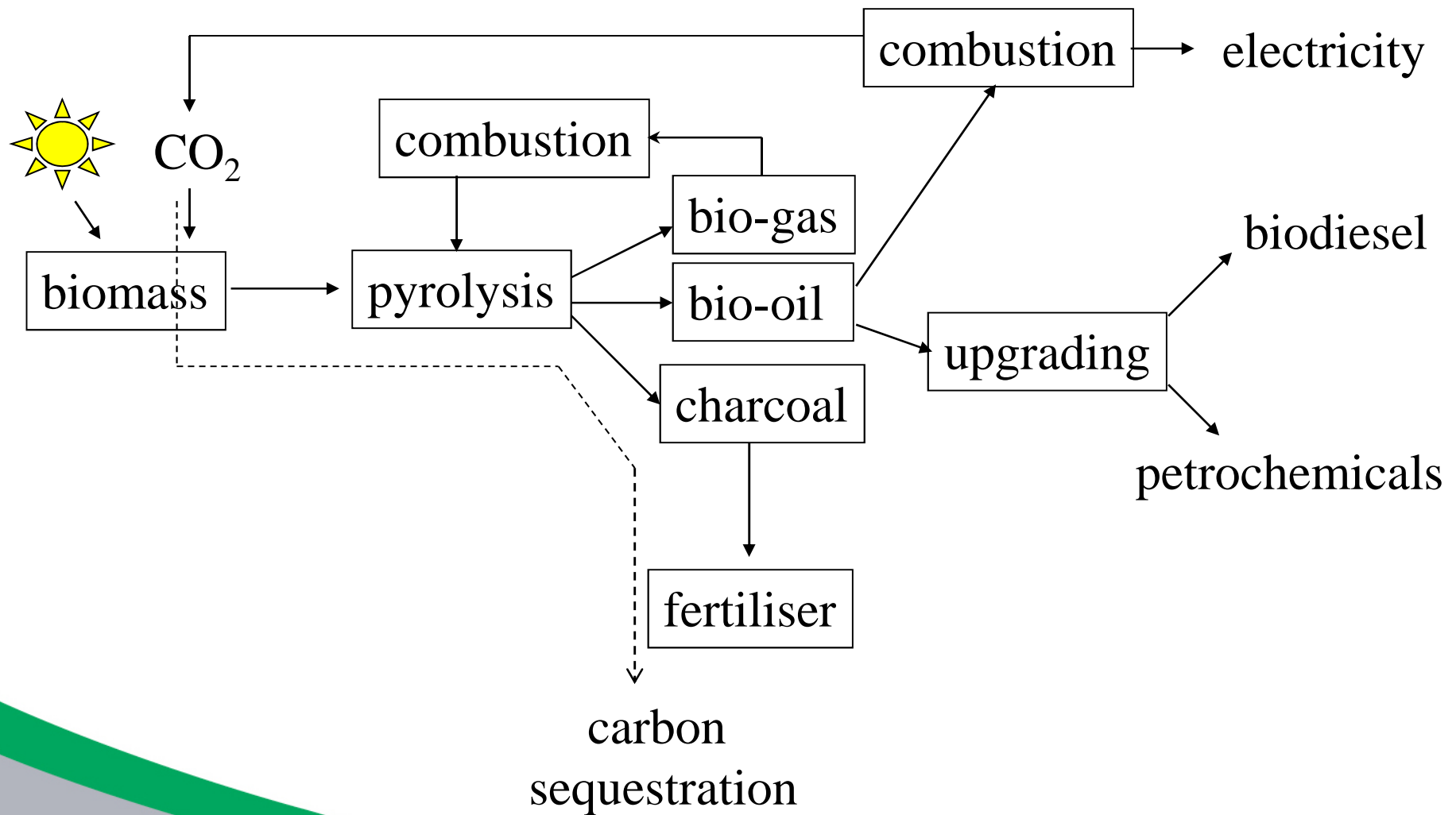
- Population growth
- Economic growth and change in lifestyle
- Energy demand
- Nutrient demand
- Pressure on soils
- Energy crops vs food products

# Managing for Sustainability

- Sustainability = Benefits / Impacts
- Forecasting vs backcasting approach to management



# System Approach to the Biochar Opportunity



# An Immodest Proposal

A Computer Scientist Looks at Biology

# Biological information today

- *Molecular Biology of the Cell* (Alberts *et al*):
  - 7 pounds (3.2 Kg)
  - 1460 pages
  - 99%: English, pictures
- *Biochemistry* (Voet & Voet):
  - 7 pounds
  - 1500 pages
  - 99%: English, pictures

# Biological *and* computer systems

- **HUGE!**
  - Thousands or millions of components
  - Complex objects
  - MANY processes that have to go just right
  - Processes and objects have hierarchical structure
  - Especially in biology: structure is a central concept

# English is lousy for describing huge systems

- Computer scientists know: English is NOT for describing big, complex systems
  - Not designed for giving precise, technical specification of systems with 1000's or 1,000,000's of interacting components
  - Not designed for giving precise specifications of structure at all levels
    - **System → subsystem → class → method → code**
    - **Organism → organ system → organ-structure → cell → organelles → biological molecules**

## Computer scientists use:

- Use case diagrams
- Class diagrams
- Sequence diagrams
- Executable code

Formal  
descriptions

- English indispensable, but not enough
- We've learned the hard way

# Role of math in physics & engineering vs. biology

- Physics, engineering, computing: structure and behavior of objects & processes of interest described with **mathematics**
- Biology: structure and behavior of objects & processes of interest described with **English and pictures**
  - No mathematics for describing the structure and behavior of the things we're interested in
    - Equations: for a few of the relationships between quantities, some of the properties
    - Behavior: single-level graphs/nets

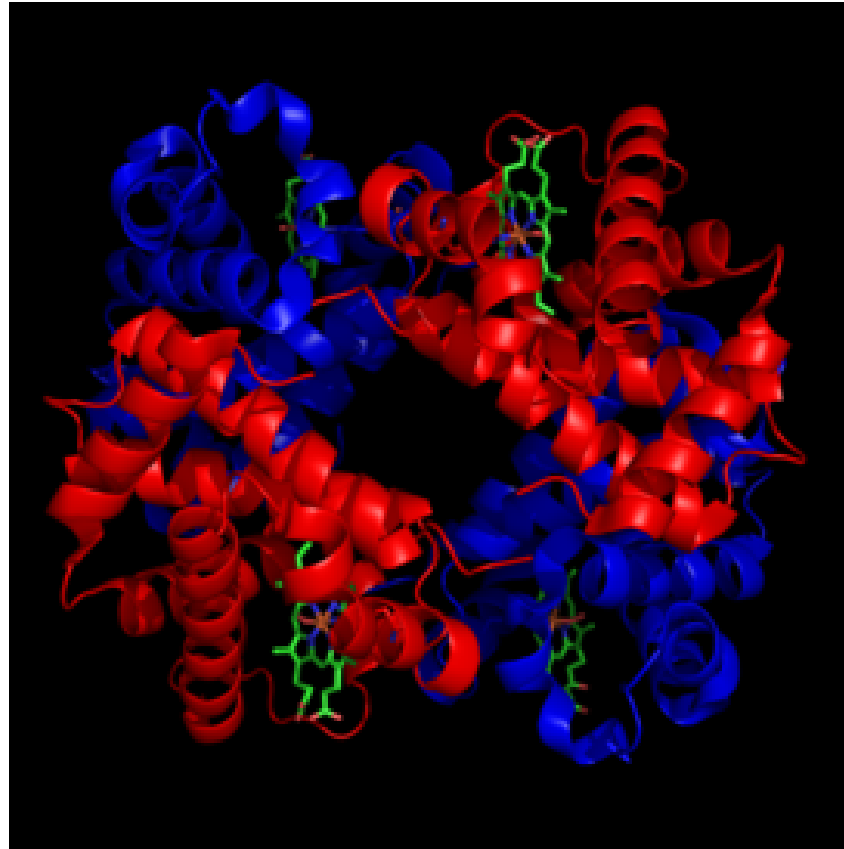
# Compare

$$i\hbar \frac{\partial}{\partial t} \Psi(\mathbf{r}, t) = \hat{H} \Psi(\mathbf{r}, t)$$

**vs.**

- The hemoglobin molecule has four globular protein subunits. Each subunit is composed of a protein chain and a non-protein heme group. Each protein chain arranges into a set of connected alpha-helix structural segments. The connected alpha-helix segments contain a pocket. The pocket binds heme group. The heme group consists of an iron ion held in a porphyrin ring. A porphyrin ring consists of four pyrrole molecules cyclically linked together with the iron ion bound in the centre. Oxygen binds to the Fe ion. When oxygen is not bound, a very weakly bonded water molecule fills the site, forming a distorted octahedron.

# Or pictures



# Result

- We cannot:
  - Quantify structural differences
    - How similar are normal hemoglobin and sickle cell hemoglobin?
    - Degree of similarity cannot be stated mathematically
  - Calculate how different structures are
  - Formally state effects of genetic changes on structures (at multiple levels)
    - Because we can't state or quantify the structure change formally
  - Search databases for similar structures

# The immodest proposal

- **Add rigor to biology**
- Devise a mathematics for describing biological things formally
  - Structures (at all levels)
  - Processes (at all levels)
  - States of affairs (at all levels)
- So that huge multi-level biological systems (e.g., a cell) can be described formally, just as computer systems are now

# One candidate: Entity Specifications

- Use (Name, Description) methodology to define objects, processes, generalized states (states of affairs)
  - Name: formal identifier of the entity
  - Description: formal identifiers for
    - The entity's parts (immediate constituents)
    - The relationships between constituents
    - *Any* relationship, not only those mathematically definable

# ES formalism

- An Entity Specification: an ordered pair (N, D), where:
  - N is the formal *name* of the object or process
  - D is the *description* of the entity: an ordered pair (C, R), where:
    - $C = \{C_i\}$ , in which  $C_i$  are the constituents
    - $R = \{R_j\}$  is the set of n-ary relationships that must hold between the named constituents.
      - Adjacent, Distance(x,y), Inside(Nucleus, chromatin), ...
      - Equations are relationship definitions

# An example of the payoff of mathematics

$$SD(A, B) =$$

Structural  
difference  
between A  
and B

$$\text{MC} \\ (NA - NB)^2 + \sum_{i=1} \text{PD}(A_i, B_i)^2 +$$

MT L

$$\sum_{j=1} \sum_{i=1} (R_i(ta_j) - R_i(tb_j))^2 +$$

MC

$$\delta \cdot \sum_{i=1} \text{SD}(A_i, B_i)^2$$

## ESs: *one way*

- The real point: **change the way math is seen by biologists**
- “Mathematics is the language of physics”
- It should be the language of biology

**VCU** Virginia Commonwealth University

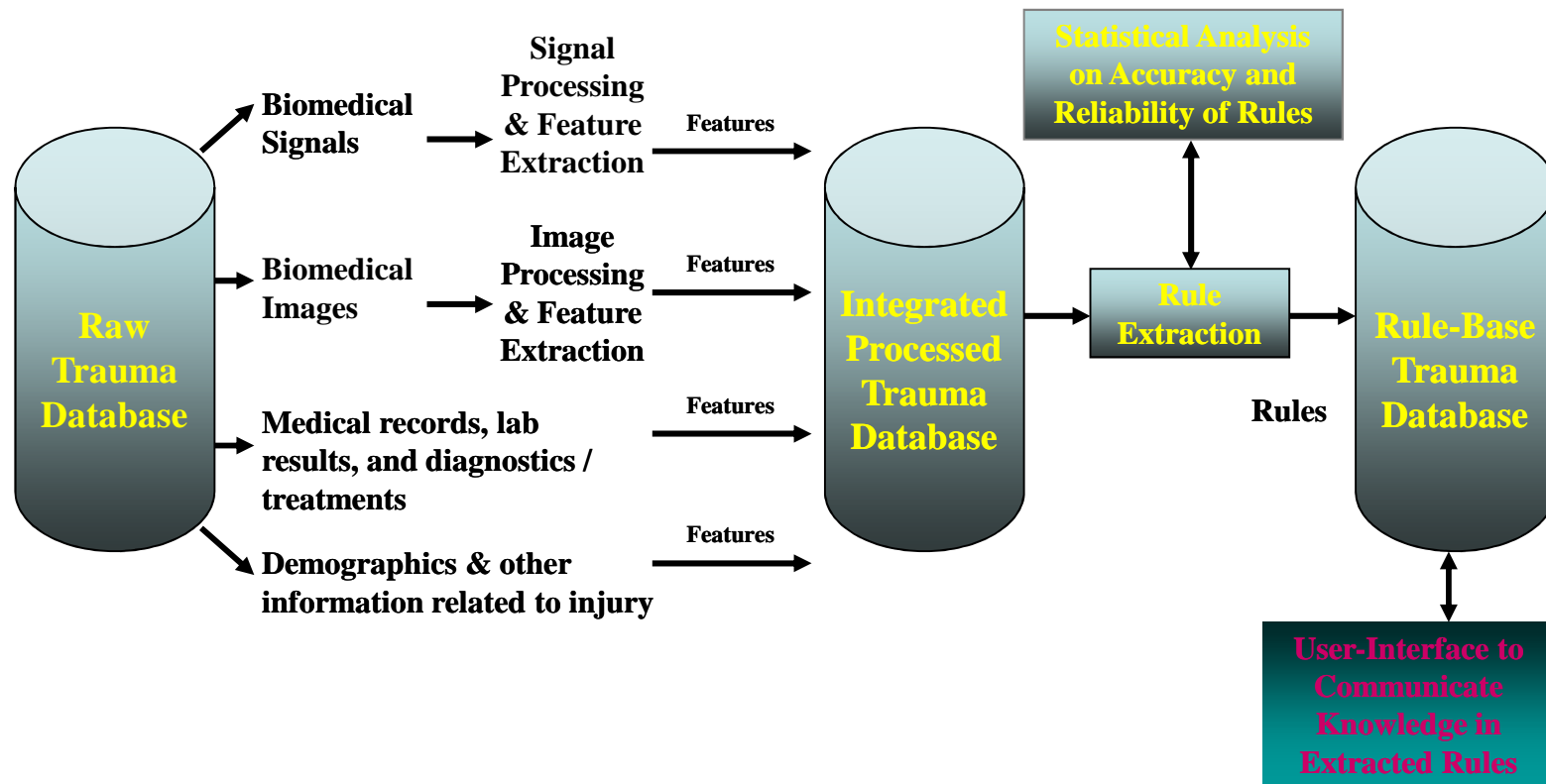
# **Challenges in Bio-technologies, Systems and Environments**

Biomedical Information Processing for  
Computer-Aided Medical Decision Making

**Kayvan Najarian**

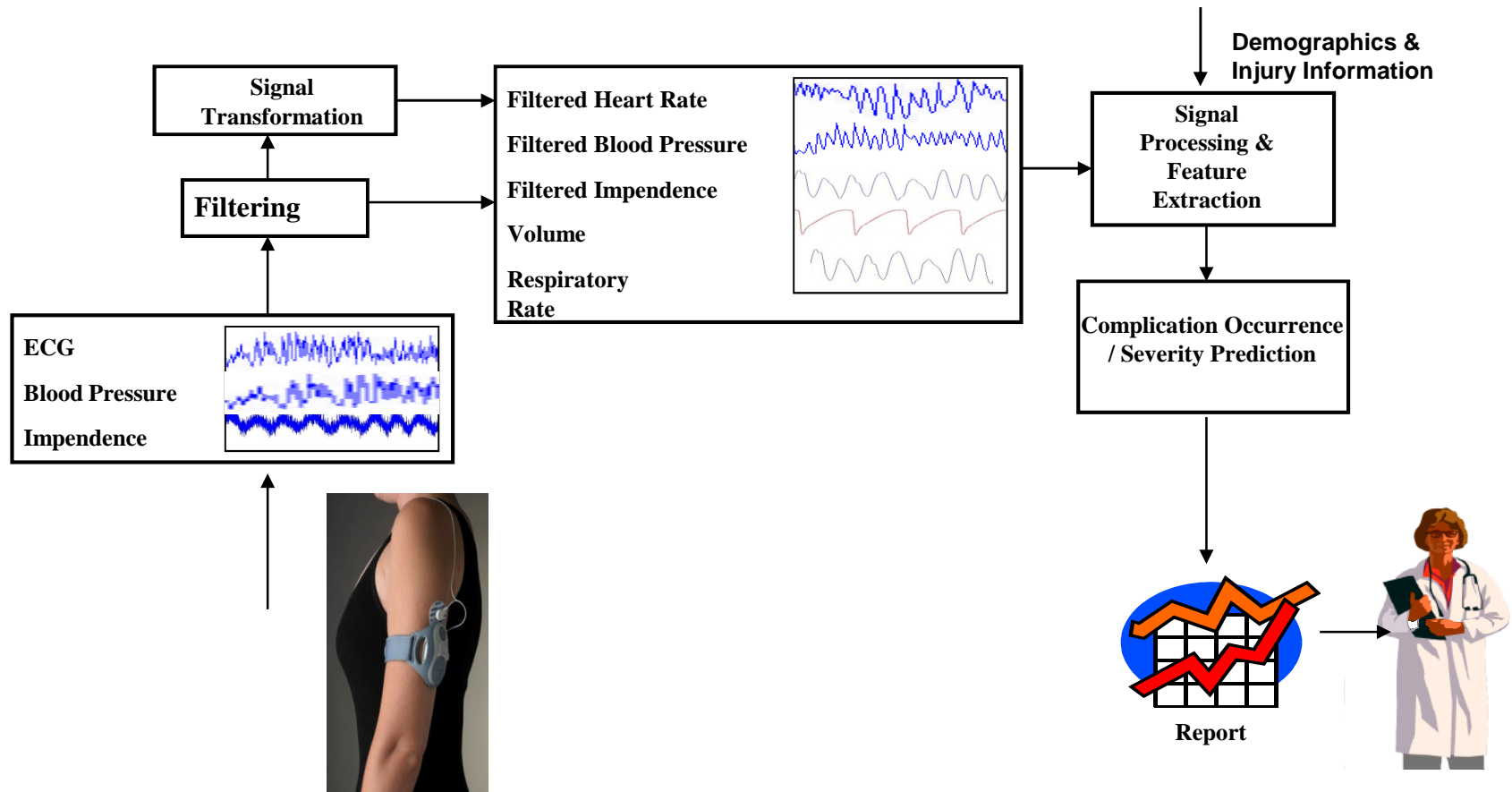
# Challenges in Bio-technologies, Systems and Environments

- Main Challenge: **Information Integration and Processing for Computer-Aided Decision Making**



# Challenges in Bio-technologies, Systems and Environments

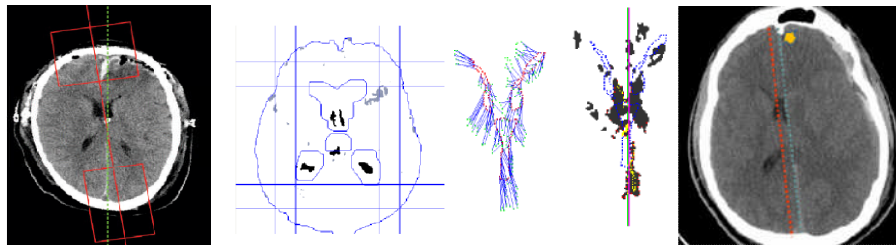
- Example I: **Portable Smart Monitoring Systems**



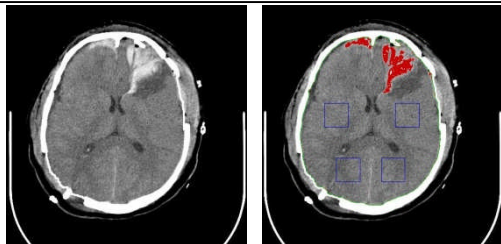
# Challenges in Bio-technologies, Systems and Environments

- Example II: TBI Decision Making Using Image Processing and Machine Learning

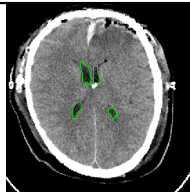
Midline Shift Detection



Quantitative Assessment of Hematoma



Volumetric Segmentation / Measurement of Ventricles



Machine Learning for prediction of:  
ICP Range  
Outcome (e.g. Survival)  
Functional Independence Measures  
Life Saving Intervention(s)  
...

# Challenges in Bio-technologies, Systems and Environments

- ❑ Future challenges
  - ❑ Incorporating genomic and proteomic information in decision-making process
  - ❑ Forming effective standards for data collection and management

**Kayvan Najarian's Biomedical Signal and Image Processing Lab**

# Challenges in Bio-technologies, Systems and Environments?

## Developing Technologies for the Bottom Billion

Considerable progress has been made over the past 50 years

- Unprecedented economic growth
- Life expectancy increase
- Agricultural product increase – A drop in food price

Yet major problems remains:

- 1.2 billion people live on less than US\$ 1 per day
- 1 billion people do not have access to clean water
- More than 2 billion people have no access to sanitation
- 1.3 billion people are breathing air below the standard consider acceptable by WHO
- 800 million people food insecure

# Challenges of Bio-technology - Health

## Typhoid Fever

- Typhoid fever or commonly just typhoid is a common worldwide illness, transmitted by the ingestion of food or water contaminated with the feces of an infected person.
- Typhoid fever remained as a public health problem in many developing countries.
- Current diagnosis for typhoid is via the method of culture and serology (Widal test). These methods lack sensitivity, specificity and speed (more than 1 day).
- TYPHIRAPID was recently and successfully developed in USM to detect typhoid in 20 minute at a cost that is only a quarter of current technology. This has made a huge impact for the bottom billion.