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

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

Challenges in Bio-technology, Systems and Environment

Vladimir Strezov

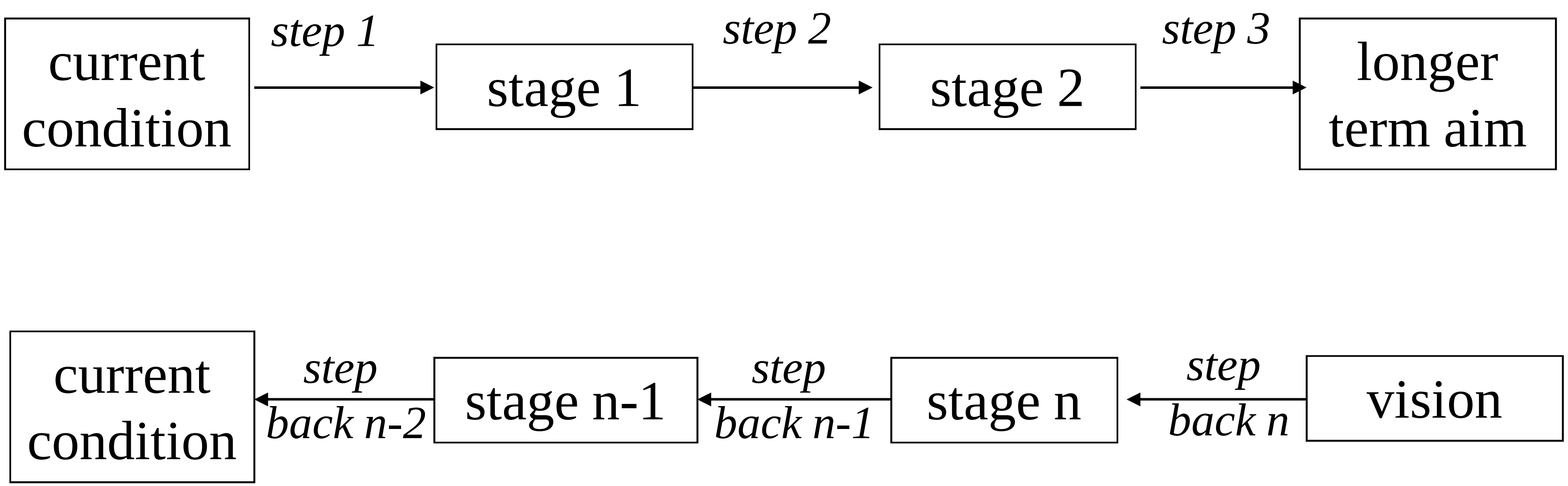
Graduate School of the Environment, Macquarie University, Australia

Challenges

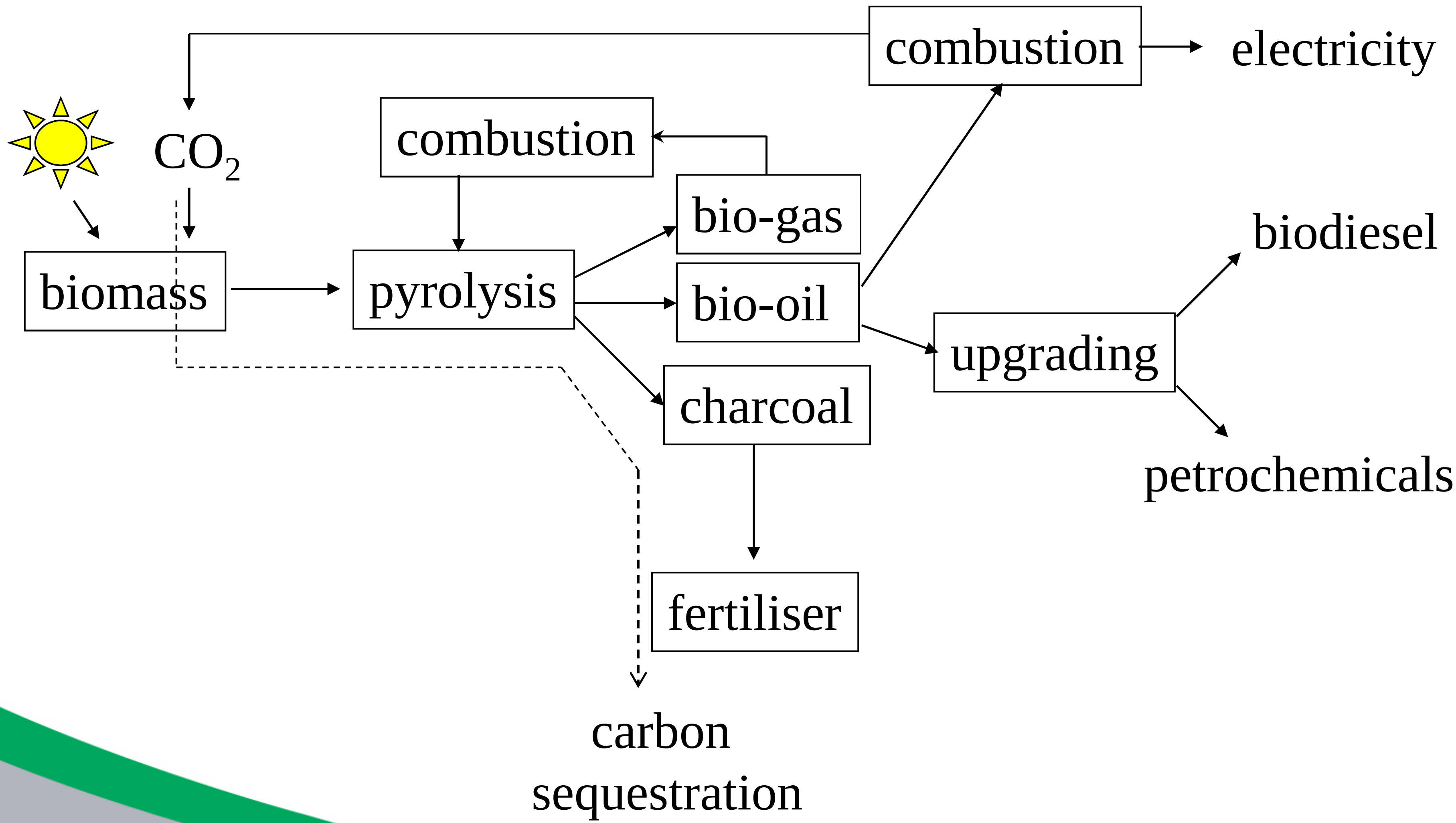
- Population growth
- Economic growth and change in lifestyle
- Energy demand
- Nutrient demand
- Pressure on soils
- Energy crops vs food products

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 descibing 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 indispensible, 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

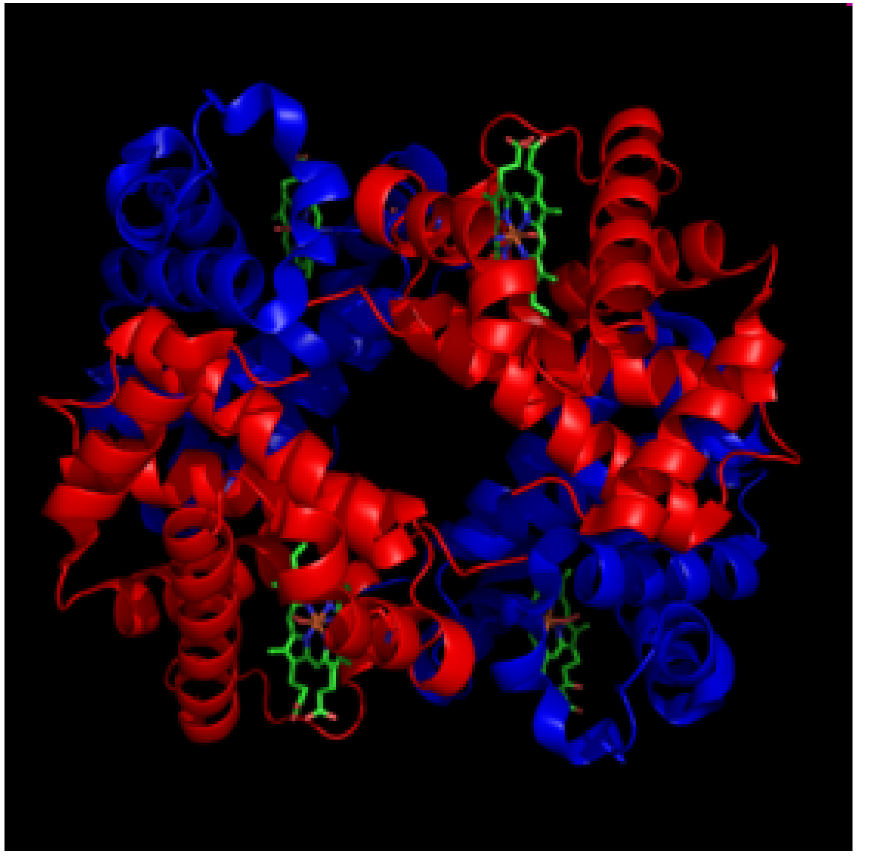
Compare

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

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:
  - <u>Quantify</u> structural differences
    - How similar are normal hemoglobin and sickle cell hemoglobin?
    - Degree of similarity cannot be stated mathematically
  - <u>Calculate</u> how different structures are
  - Formally <u>state</u> 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

$$SD(A, B) = \sqrt{(NA-NB)^2 + \sum_{i=1}^{MC} PD(A_i, B_i)^2 + \sum_{j=1}^{MT} \sum_{i=1}^{L} (R_i(ta_j) - R_i(tb_j))^2 + \delta \cdot \sum_{i=1}^{MC} SD(A_i, B_i)^2}$$

Structural difference between A and B

ESs: *one* way

- The real point: **change the way math is seen by biologists**
- "Mathematics is the language of physics"
- It <u>should</u> be the language of biology

VCU **Virginia Commonwealth University**

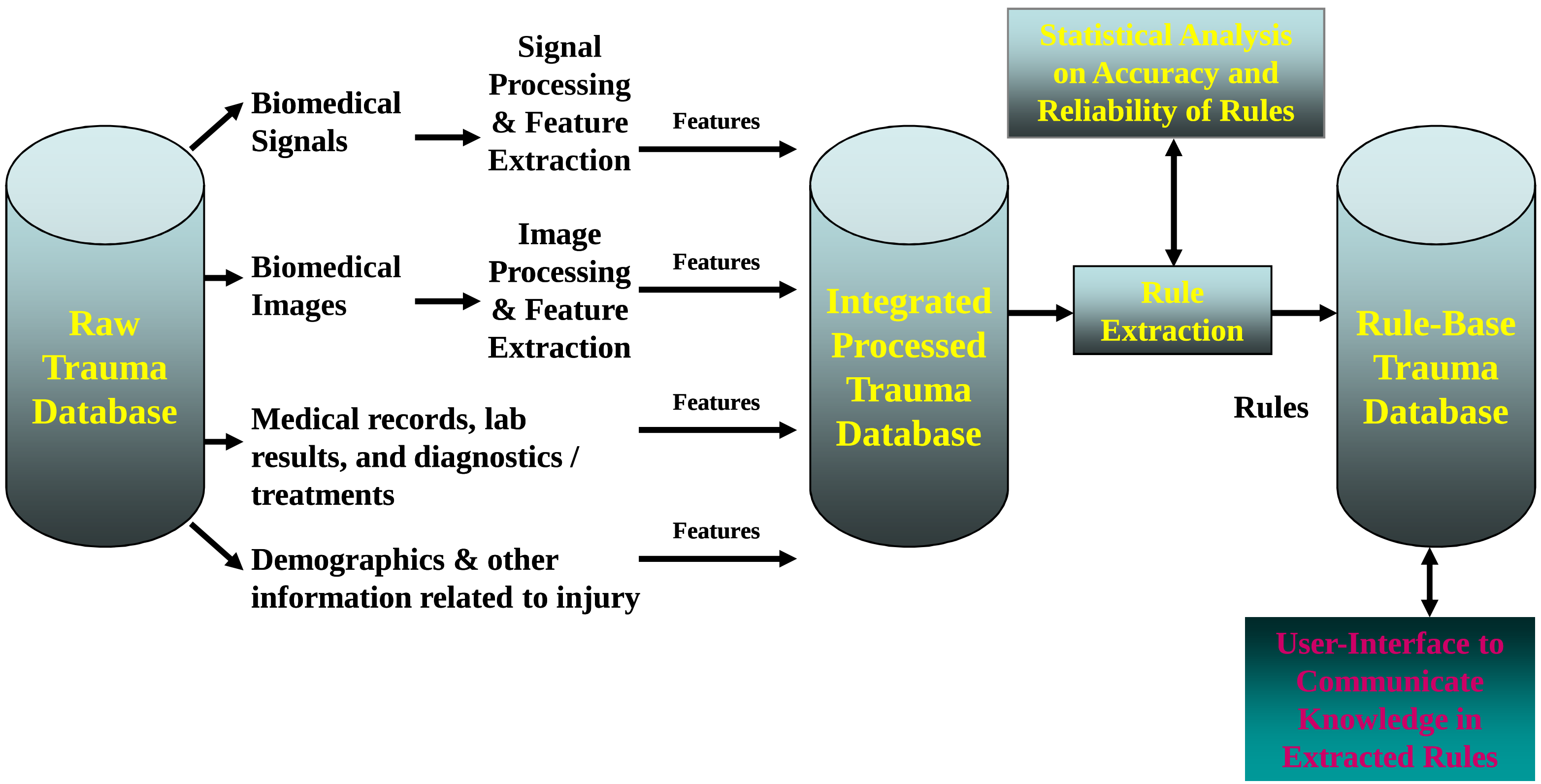
Challenges in Bio-technologies, Systems and Environments

Biomedical Information Processing for Computer-Aided Medical Decision Making

Kayvan Najarian

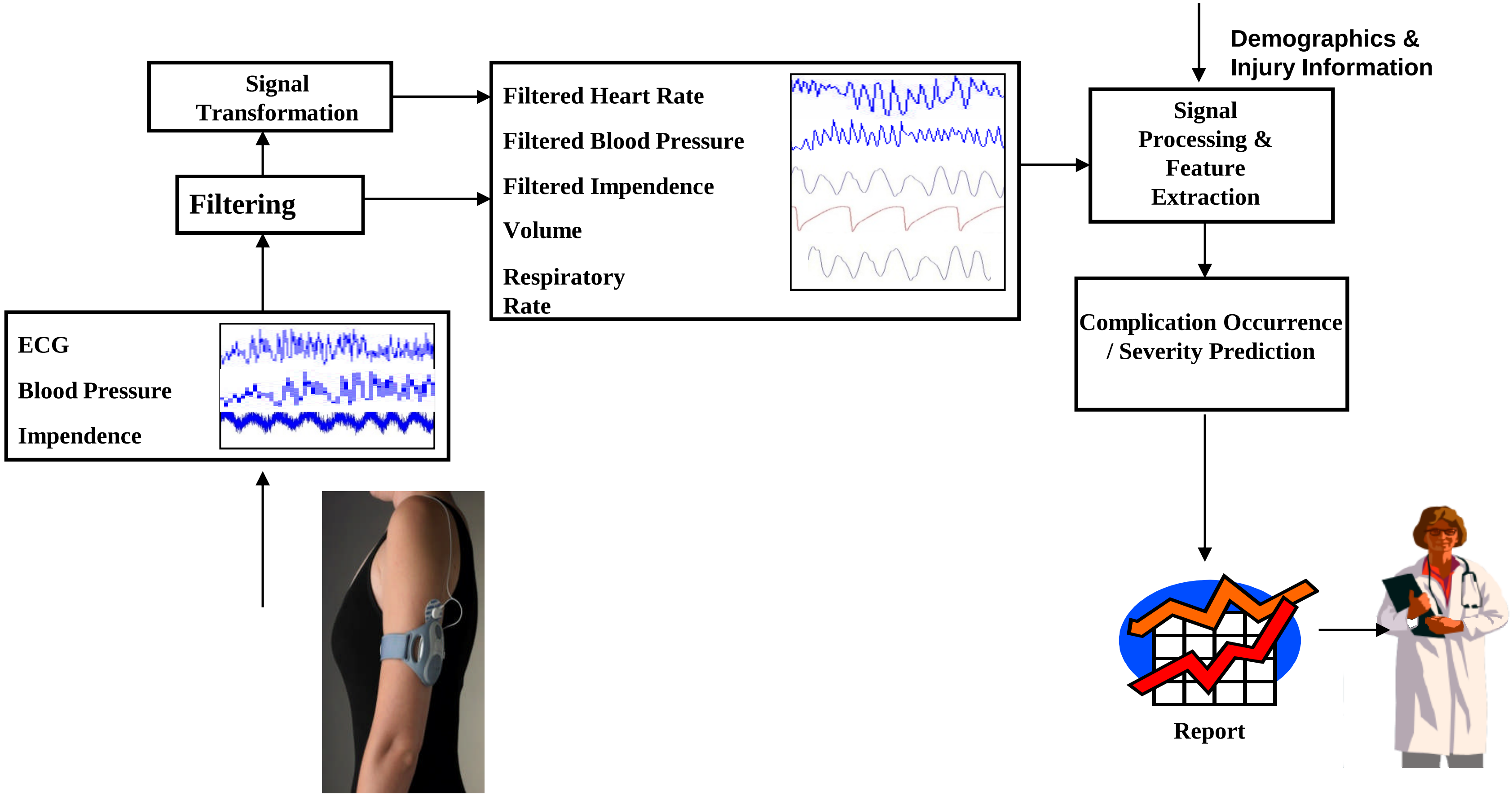
Challenges in Bio-technologies, Systems and Environments

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



Challenges in Bio-technologies, Systems and Environments

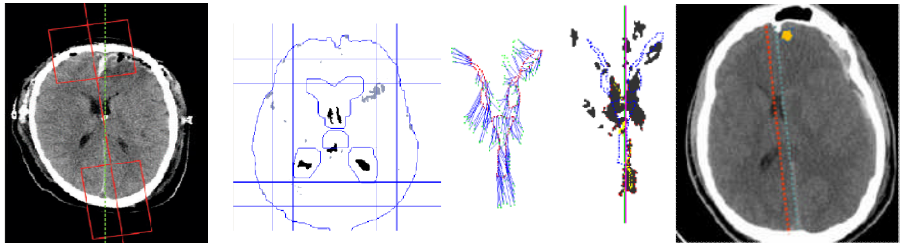
- Example I: Portable Smart Monitoring Systems



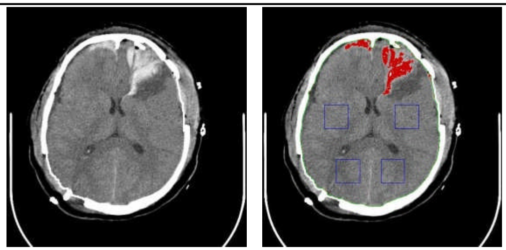
Challenges in Bio-technologies, Systems and Environments

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

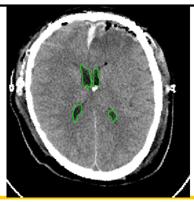
Midline Shift Detection



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 managment

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.