Position Statement
for the Panel on
“Informatics: What is it?
What are particular research challenges
with respect to sensor networks?”
at
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Outline

- Scope of Informatics
- Concepts
  - Informatics
  - Information
- Informatics Questions
  - Operational questions
  - Spatio-temporal scale questions
- Informatics and Challenges facing Humanity
  - Example
- Musings on Sensor Related Challenges
(Geo) Informatics across Disciplines!
Informatics – Concepts

- **Information**
  - related to notions of constraint, communication, control, data, form, instruction, knowledge, meaning, mental stimulus, pattern, perception, and representation.

- **Information Processing**: 
  - change (processing) of information in any manner detectable by an observer.

- **Information Systems**: 
  - system of persons, data records and activities that process the data and information in a given organization, including manual processes or automated processes.
Outline

Scope of Informatics

Concepts

Informatics

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Spatio-temporal scale questions

Informatics and Challenges facing Humanity

Example

Musings on Sensor Related Challenges
Information Concepts

- **Data**
  - collection of natural phenomena descriptors, e.g. results of experience, observation or experiment, or a set of premises.

- **Representation**
  - Way to store knowledge for programs to process it
  - Ex. numbers, words, images (measurements or observations of a set of variables)

- **Form**
  - shape, appearance, or configuration, of an object

- **Knowledge**
  - what is known in a particular field or in total; facts and information

- **Pattern**
  - a theme of predictably reoccurring events or objects

- **Instruction**
  - command and explanation for how an action, behavior, method, or task is to be begun, completed, conducted, or executed.
Information Concepts - 2

- **Linguistics**: **Meaning**
  - Semantics deals most directly with what words or phrases mean,
  - Pragmatics deals with how the environment changes the meanings of words.

- **Cognitive Science**
  - Mental stimulus: action of various agents (stimuli) on muscles, nerves, or a sensory end organ, to activate part connected with the nerve
  - Perception: process of attaining awareness or understanding of sensory information
  - Representation: concerned with how people store and process information
  - Knowledge - "justified true belief", e.g.
    - awareness or familiarity gained by experience of a fact or situation.
    - expertise, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject

- **Information Theory**
  - Constraint - degree of statistical dependence between or among variables
  - Communication - process of transferring information from a sender to a receiver with the use of a medium
  - Control – device(s) to manage, command, direct or regulate the behavior of other devices or systems.
Informatics – What is it?

- Variety of meanings in dictionary
  - Study of information processing; computer science!
  - Information science
  - Science of gathering, manipulating, storing, retrieving, and classifying recorded information
  - Collection, classification, storage, retrieval, and dissemination of recorded knowledge

- An Opinion
  - Science of information
    - Conceptual and theoretical foundations – new & adapted
  - Systems: engineering of information systems
    - Structure, algorithms, behavior, and interactions of systems to
      - store, process, access and communicate information.
  - Services: practice of information processing
    - Computational, cognitive and social aspects
    - E.g. study of the social impact of information technologies.

- Sources:
  - Wikipedia, Dictionary.com, M. Goodchild, Personal Interpretation
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Informatics Questions: Operational View

• How do we conceptualize Physical and Cyber (P&C) worlds?

• How do we measure P&C concepts, recognize them in (remotely) sensed information or in the field, and identify their accuracy and quality?

• How do we represent P&C concepts with incomplete/ uncertain information, with alternative data models, and possibly with multiple representations for the same data, in digital environments?

• How do we store, access, and transform P&C concepts, facilitating data sharing, data transfer, and data archiving, while ensuring minimum information loss?

• How do we explain P&C phenomena through the application of appropriate methods of forward or inverse models of physical and human processes?

• How do we visualize P&C concepts on a variety of media such as maps on electronic displays or animated displays?

• How do we use P&C concepts to think about spatio-temporal phenomena, and to seek explanations for spatio-temporal patterns and phenomena?

• Source: Adaptation from NCGIA proposal to NSF by Goodchild et al.
Informatics Questions: Spatio-Temporal Scale

- **Level 1**: Process *local* raw data measured by a sensor, e.g. thresholding

- **Level 2**: Multi-sensor correlation for *focal* or teleconnection
  - Triangulation to position a moving object
  - Identify anomalies across sensors (e.g. discontinuity)

- **Level 3**: Aggregate common *global* operation picture
  - Interpret events in context, Develop hypothesis about current events
  - Knowledge Discovery - maps, descriptive models, visualization
  - Data Mining - Descriptive models: clusters, trends, associations, ...

- **Level 4**: Prediction (e.g. via forward/inverse models) of *process*
  - Predict future states, e.g. final states (goals) and
  - Explain cause (intent/drivers/phase changes)

- **Level 5 – Action, System Optimization**:
  - How to redirect intelligence, surveillance, and reconnaissance (ISR) to improve performance (e.g. get better sensor utilization)
Local Informatics: Hotspots

- Activity over
  - Spatial Networks
  - Time
- Scale
  - Spatial: neighborhood
  - Time: 24 hours
Global Scale over years

- Teleconnection
  - Find (land location, ocean location) pairs with correlated climate changes
    - Ex. El Nino affects climate at many land locations

Average Monthly Temperature
(Courtesy: NASA, Prof. V. Kumar)

Global Influence of El Nino during the Northern Hemisphere Winter
(D: Dry, W: Warm, R: Rainfall)
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Informatics & Challenges facing Humanity

- Is Informatics relevant to challenges facing humanity?
- Next Decade Global Challenges [Millenium Project, United Nations]
  - Sustainable development for all
  - Clean water
  - Make information and communication technologies work for all
  - Reduce threat of new and reemerging diseases …
  - Stop transnational organized crime networks
  - Meeting growing energy demands safely and efficiently
  - Shared values and security strategies to reduce conflict, terrorism, WMD
  - … (8 more)
- What are the implications for Informatics?
  - Example: National Geospatial Intelligence Agency
  - Role for many disciplines!
NGA Informatics Needs: Role for Computer Science, Physics, Engineering, etc.

**Above Surface**
- Static
- Moving

Traditional NTM Coverage

**Below Surface**
- Characterized
- Uncharacterized

**Denial and Deception**
- 0 - 4 Hours
- 4 - 12 Hours
- 12 - 24 Hours

Source: Greg Smith - NGA
Geospatial Intelligence

Recorded View

(2) Situational Awareness

**

How many SAMS have moved more than 25 miles today?

Predictive View

(4) Knowledge Discovery

**

What other events could occur with this pattern?

(1) Data Base Maintenance

- GKB-F
- NES
- MIDB
- NGL
- M3
- RMS

Captures observations and information needs

(3) Predictive Analysis

**

From known patterns, which movement does this represent?

Source: Greg Smith - NGA
THIS MODERN WORLD

IT'S HARD TO KEEP TRACK OF ALL THE INVASIVE NEW TECHNOLOGIES BEING IMPLEMENTED FOR OUR OWN GOOD.

---YOU SEE, WE HOPE TO IMPLANT ONE OF THESE GLOBAL POSITIONING IDENTITY CHIPS IN THE CRANIUM OF EVERY LIVING AMERICAN--

---TO HELP THEM FIND THEIR WAY HOME IF THEY EVER GET LOST! WE ONLY WANT TO HELP!

AND IN NEW HAVEN, CONNECTICUT, THE ACME RENT-A-CAR COMPANY RECENTLY INSTALLED A SOPHISTICATED G.P.S. TRACKING SYSTEM IN ITS FLEET--AND BEGAN CHARGING CUSTOMERS $150 EACH TIME THE SYSTEM CAUGHT THEM SPEEDING... *

BY THE AUTHORITY VESTED IN ME AS A SMALL BUSINESS OWNER, I HEREBY FINE YOU $450! LET THIS BE A LESSON TO YOU, YOUNG MAN!

---ACME RENT-A-CAR--- "WE KEEP AN EYE ON YOU!" AND THANKS FOR CHOOSING ACME! WE APPRECIATE YOUR BUSINESS!

*THIS IS ALSO TRUE.fortunately, ACME HAS JUST BEEN ORDERED TO CEASE THE PRACTICE AND REFUND THE "FINES."

IN TAMPA, FLORIDA, HIGH-TECH SPY CAMERAS LINKED TO A POLICE DATABASE SCAN CROWDS ON PUBLIC STREETS, SEARCHING FOR WANTED CRIMINALS... WHICH MEANS YOU CAN BE STOPPED BY POLICE AT ANY TIME IF YOU HAPPEN TO RESEMBLE A KNOWN FELON...

I HAD NO IDEA MY HUSBAND WAS A PSYCHOPATHIC KILLER, OFFICER!

WE'VE GOT AN EIGHTY-FIVE PERCENT BIOMETRIC IMAGING MATCH, MA'AM! YOU'RE LUCKY TO BE ALIVE!

*THIS IS TRUE, IF THE VISUAL RECOGNITION SOFTWARE SCORES A MATCH OF 8.5 OR HIGHER (ON A SCALE OF 1-10), OFFICERS ARE DISPATCHED TO QUESTION THE "SUSPECT."

OF COURSE, PROponents OF SUCH TACTICS ALWAYS JUSTIFY THEM IN THE NAME OF PUBLIC SAFETY... AND ANYWAY, IF YOU'RE NOT DOING ANYTHING WRONG, YOU DON'T HAVE ANYTHING TO WORRY ABOUT... RIGHT?

SIR, YOUR G.P.S. CRANIAL IMPLANT PLACES YOU AT THE CORNER OF BROADWAY AND FOURTEENTH AT 12:07 P.M. YESTERDAY--CROSSING AGAINST THE LIGHT!

JAYWALKING IS A CRIME IN THIS CITY, SIR! I'M AFRAID YOU'LL HAVE TO COME WITH US!

WE'VE ALSO GOT SOME QUESTIONS ABOUT YOUR RE-CYCLING HABITS.

---BY TOM TOMORROW--- 07-11-01... IT'S THE PENGUIN TO THE NEW HAVEN ADVOCATE...
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(Wireless) Sensor Networks

- Components
  - spatially distributed autonomous devices using sensors
  - to cooperatively monitor physical or environmental conditions,
  - such as temperature, sound, vibration, pressure, motion or pollutants,
  - at different locations

- Unique characteristics include:
  - Limited power they can harvest or store
  - Ability to withstand harsh environmental conditions
  - Ability to cope with node failures
  - Mobility of nodes
  - Dynamic network topology
  - Communication failures
  - Heterogeneity of nodes
  - Large scale of deployment
  - Unattended operation
What are particular (informatics) research challenges with respect to sensor networks?

- New Aspects
  - Spatio-temporal Framework
  - Streaming Nature
  - Resource Constraint – power, communication, computing, …
  - Sensor Fusion

- Q? What are gaps in information science, systems and services?
What are particular (informatics) research challenges with respect to sensor networks?

- Information Science
  - Accuracy, Precision, Measurement errors/imprecision
  - Data Representation: numbers → probability distributions, OGIS → …
  - Operations on new representations
  - …

- Information Systems
  - Spatio-temporal Framework
  - Sensor Fusion
  - Streaming Nature
  - Resource Constraint

- Information Services
Spatio-temporal research challenges from sensor networks?

- Spatio-temporal framework – table from MN future proposal
  - Issue for statistics and data mining methods!
    - Lack of independence among measurements
  - Issues for database management systems
    - Spatio-temporal data types, query language, indexing, …
  - Issues for ontologies
    - What is a set of concepts to represent and communicate sensor network data?
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