imagine
imagine when

farm helper
tags blight, corn
meets

Farm Helper
with this

- Latitude: 38° 57’36” N
- Longitude: 95° 15’12” W
- Date: 10-9-2007
- Time: 1345h
that is sent to

Sensor Data Resource

Weather Resource

Structured Data Resource

Geocoder

Services Resource

Location

Lat-Long

Farm Helper

Date /Time

Weather Data

Weather data

Soil Information

Pest information

Lawrence, KS
and
Six billion brains
imagination today
impacts our experience tomorrow
Computing For Human Experience: Sensing, Perception, Semantics, Social Computing, Web 3.0 and beyond

Keynote @ Workshop on Emerging Topics in Engineering, DAIICT, July 2009

Amit P. Sheth,
LexisNexis Ohio Eminent Scholar
Director, Kno.e.sis center, Wright State University

knoesis.org

Thanks: K. Gomadam, M. Nagarajan, C. Thomas, C. Henson and Kno.e.sis Researchers
“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it. Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as a walk in the woods.”
Mark Weiser, *The Computer for the 21st Century* (Ubicomp vision)

“We're crying out for technology that will allow us to combine what we can do on the Internet with what we do in the physical world.”
Ian Pearson in *Big data: The next Google*
But we are not just talking about

Ubicomp: Mark Wisner and others

*Intelligence @ Interface*: Gruber – “the system knows about us, our information, and our physical environment. With knowledge about our context, an intelligent system can make recommendations and act on our behalf.”
What is CHE? Beyond better human interaction

- Focus in the past (egUbicomp): How humans interact with the system (computer, Internet)
- Our focus—almost the reverse of the past (and both are needed)
- Computing for Human Experience is about: How computing serves, assists and collaborates with humans to complement and enrich their normal activities
  - nondestructively and unobtrusively, with minimal explicit concern or effort on part of humans
  - anticipatory, knowledgeable, intelligent, implicit, ubiquitous
  - Computing that encompasses semantic, social, service, sensor and mobile Web
Principals of CHE

- Human is the master, system is the slave
- Human sees minimal changes to normal behavior and activity, system is there to serve/assist/support in human’s natural condition
  - Search, browsing, etc are not primary; HCI is not the focus
  - Getting the assistance and answers are important, improving experience is key
- Multimodal, multisensory and participatory environment
- Integrated and contextual application of (not just access to) sensor data, databases, collective intelligence, wisdom of the crowd, conceptual models, reasoning
Learning from a number of exciting visions

<table>
<thead>
<tr>
<th>Name</th>
<th>Vision/Project</th>
<th>Year(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vannevar Bush</td>
<td>Trailblazing, Memex (<a href="https://books.google.com/books?id=VUo1AAAAMAAJ">As We May Think</a>)</td>
<td>1945</td>
</tr>
<tr>
<td>Zelkha, Epstein</td>
<td>Ambient Intelligence</td>
<td>1998 -</td>
</tr>
<tr>
<td>Tim Berners-Lee</td>
<td>Semantic Web</td>
<td>1999 -</td>
</tr>
<tr>
<td>Gordon Bell et al</td>
<td><a href="https://www.mylifebits.org">MyLifeBits</a></td>
<td>2002</td>
</tr>
<tr>
<td>Jonathan Rossiter</td>
<td><a href="https://www.humanist.org.uk">Humanist Computing</a></td>
<td>2003</td>
</tr>
<tr>
<td>Ramesh Jain</td>
<td><a href="https://www.expecon.com">Experiential Computing</a></td>
<td>2003</td>
</tr>
<tr>
<td>ITU</td>
<td><a href="https://www.iet.org">The Internet of Things</a></td>
<td>2005</td>
</tr>
<tr>
<td>Ramesh Jain</td>
<td><a href="https://www.eventweb.org">Event Web</a></td>
<td>2006-2008</td>
</tr>
<tr>
<td>A. Sheth et al</td>
<td><a href="https://www.senven.com">Relationship Web</a> (also, Spatio-temporal-thematic analysis, Semantic Sensor Web)</td>
<td>2006-2008</td>
</tr>
<tr>
<td>Tom Gruber</td>
<td><a href="https://www.knoesis.org">Intelligence @Interface</a></td>
<td>2008</td>
</tr>
</tbody>
</table>
Physical-Cyber divide is narrowing

Psyleron’s Mind-Lamp (Princeton U), connections between the mind and the physical world.

Neuro Sky’s mind-controlled headset to play a video game.

MIT’s Fluid Interface Group: wearable device with a projector for deep interactions with the environment.

Sensing emotion is increasingly possible and sensors are being developed to capture emotions.
Web (and associated computing) is evolving

Computing for Human Experience
- Web as an oracle / assistant / partner
  - "ask the Web": using semantics to leverage text + data + services
  - Powerset

Web of people
- social networks, user-created casual content
  - Twine, GeneRIF, Connotea

Web of resources
- data, service, data, mashups
- ubiquitous/mobile computing

Web of databases
- dynamically generated pages
- web query interfaces

Web of pages
- text, manually created links
- extensive navigation
Sensing, Observing, Perceptual, Semantic, Social & Participatory, Experiential

also everyone, anytime, anywhere
Consider

- that all objects, events and activities in the physical world have a counterpart in the Cyberworld (IoT)
- multi-facted context of real world is captured in the cyberworld (multilevel & citizen sensors/participatory sensing)
- each object, event and activity is represented
  - with semantic annotations (semantic sensor web)
- for a chosen context, with an ability to explicate and associate variety of relationships and events (Relationship Web, EventWeb)
- appropriate reasoning and human/social interaction are available and applied, insights extracted (semantic web, social semantic web, experiential computing)
- Activity anticipated/answers obtained/decisions reached/communicated/applied
Paradigm shift ...participatory sensing

- Where humans act as sensors or observers
- Around them is a network of sensors, computing and communicating with each other
  - Processing and delivering multi-modal information
  - Collective Intelligence
- Information-centric to Experience-centric era
  - Modeling, processing, retrieving event level information
- Use of domain knowledge
  - ....
- Understanding of casual text
Today’s Sensor Network Types

• Inert, fixed sensors

• Carried on moving objects
  – Vehicles, pedestrians (asthma research)
  – Anonymous data from GPS-enabled vehicles, toll tags, and cellular signaling to mark how fast objects are moving – and overlaying that information with location data and maps (traffic.com, Nokia experiment, …)
Today’s Network of Sensors

- Are sensing, computing, transmitting

- Are acting in concert
  - Sharing data
  - Processing them into meaningful digital representations of the world

- Researchers using 'sensor webs' to ask new questions or test hypotheses

- 2009: 1.1 billion PCs, 4 billion mobile devices, 40+ billion mobile sensors  
  (Nokia: Sensing the World with Mobile Devices)
Citizen Sensors

- Human beings
  - 6 billion intelligent sensors
  - informed observers
  - rich local knowledge
  - uplink technology
    - broadband Internet
    - mobile phone

Christmas Bird Count
Citizen Science

• Networks of amateur observers
  – possibly trained, skilled

  – thousands of volunteer participants
  – Protocols

• Project GLOBE
  – an international network of school children
  – reporting environmental conditions
  – central integration and redistribution
Citizen Sensor – Humans Actively Engage

• In connecting, searching, processing, stitching together information

• Asks, gets.. Asks again, gets again…

Images credit – flickr.com
mumbai, india
november 26, 2008
another chapter in the war against civilization
and
Bombay Blast by Vinu
sameer_gupta: Why is Australian government issuing advisory to not to visit Mumbai? The govt. is nuts cos it gives more confidence to ppl spreading terror.
Mumbai, India
Nov 27, 2008 11:59 PM GMT · Reply · View Tweet

sameer_gupta: CNBC is reporting that so far 7 terrorists have been killed in Taj Mahal. #mumbai
Mumbai, India
Nov 27, 2008 11:46 PM GMT · Reply · View Tweet

Mumbai: #mumbai Situation Report: mostly static. Cleanup operations at Taj, Oberoi and Nariman still in flux. Other reported attacks are rumors.
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Mumbai, India
Nov 27, 2008 11:33 PM GMT · Reply · View Tweet
the world saw it

Through the eyes of the people
the world read it
Through the words of the people
PEOPLE told their stories to PEOPLE
A powerful new era in Information dissemination had taken firm ground
Making it possible for us to create a global network of citizens

Citizen Sensors – Citizens observing, processing, transmitting, reporting
18 Hormusji Street, Colaba

Address to location database

VasantVihar

Nariman House

Income Tax Office

Spatio-Temporal Analysis

Identify and extract information from tweets

Mumbai: #mumbai Situation Report: mostly static. Cleanup operations at Taj, Oberoi and Nariman still in flux. Other reported attacks are rumors.
Mumbai, India
Nov 27, 2008 11:37 PM GMT · Reply · View Tweet

sameer gupta: Atleast 5-6 people held hostage in Nariman House. More than 50 NSG men surrounding the building. #mumbai
Mumbai, India
Nov 27, 2008 11:59 PM GMT · Reply · View Tweet
Research Challenge #1

• Spatio Temporal and Thematic analysis
  – What else happened “near” this event location?
  – What events occurred “before” and “after” this event?
  – Any message about “causes” for this event?
Spatial Analysis....

Which tweets originated from an address near 18.916517°N 72.827682°E?

sameer_gupta: Atleast 5-6 people held hostage in Nariman House. More than 50 NSG men surrounding the building. #mumbai
Mumbai, India
Nov 27, 2008 11:59 PM GMT · Reply · View Tweet

sameer_gupta: Why is Australian government issuing advisory to not to visit Mumbai? The govt. is nuts cos it gives more confidence to ppl spreading terror
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Mumbai, India
Nov 27, 2008 11:33 PM GMT · Reply · View Tweet
Which tweets originated during Nov 27th 2008, from 11PM to 12 PM

**sameer_gupta**: Atleast 5-6 people held hostage in Nariman House. More than 50 NSG men surrounding the building. #mumbai
Mumbai, India
Nov 27, 2008 11:59 PM GMT · Reply · View Tweet

**sameer_gupta**: Why is Australian government issuing advisory to not to visit Mumbai? The govt. is nuts cos it gives more confidence to ppl spreading terror
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Mumbai, India
Nov 27, 2008 11:33 PM GMT · Reply · View Tweet
Giving us

Tweets originated from an address near 18.916517°N, 72.827682°E during time interval 27th Nov 2008 between 11PM to 12PM?
Research Challenge #2: Understanding and Analyzing Casual Text

- Casual text
  - Microblogs are often written in SMS style language
  - Slangs, abbreviations
Understanding Casual Text

- Not the same as news articles or scientific literature
  - Grammatical errors
    - Implications on NL parser results
  - Inconsistent writing style
    - Implications on learning algorithms that generalize from corpus
Nature of Microblogs

- Additional constraint of limited context
  - Max. of $\times$ chars in a microblog
  - Context often provided by the discourse
- Entity identification and disambiguation
- Pre-requisite to other sophisticated information analytics
NL understanding is hard to begin with..

• Not so hard
  – “commando raid appears to be nigh at Oberoinow”
    • Oberoi = Oberoi Hotel, Nigh = high

• Challenging
  – new wing, live fire @ taj 2nd floor on iDesi TV stream
    • Fire on the second floor of the Taj hotel, not on iDesi TV
Social Context surrounding content

• Social context in which a message appears is also an added valuable resource

• Post 1:
  – “Hareemane House hostages said by eyewitnesses to be Jews. 7 Gunshots heard by reporters at Taj”

• Follow up post
  – that is Nariman House, not (Hareemane)
• I say: “Your music is wicked”

• What I really mean: “Your music is good”
Your smile rocks Lil

MusicBrainz Taxonomy

Artist: Lilly Allen
Track: Smile

Semantic Metadata: Smile is a Track
Lil transliterates to Lilly Allen
Lilly Allen is an Artist

Sentiment expression: Rocks
Transliterates to: cool, good

Structured text
(biomedical literature)

Informal Text
(Social Network chatter)

Multimedia
Content and Web data

Web Services

Urban Dictionary
Example: Pulse of a Community

- Imagine millions of such informal opinions
  - Individual expressions to mass opinions
- “Popular artists” lists from MySpace comments

  Lilly Allen
  Lady Sovereign
  Amy Winehouse
  Gorillaz
  Coldplay
  Placebo
  Sting
  Kean
  Joss Stone
What Drives the Spatio-Temporal-Thematic Analysis and Casual Text Understanding

Semantics with the help of

1. Domain Models
2. Domain Models
3. Domain Models
(ontologies, folksonomies)
Domain Knowledge: A key driver

- Places that are nearby ‘Nariman house’
  - Spatial query
- Messages originated around this place
  - Temporal analysis
- Messages about related events / places
  - Thematic analysis
Research Challenge #3
But Where does the Domain Knowledge come from?

- Expert and committee based ontology creation ... works in some domains (e.g., biomedicine, health care,...)
- Community driven knowledge extraction
  - How to create models that are “socially scalable”?
  - How to organically grow and maintain this model?
Building models...seed word to hierarchy creation using WIKIPEDIA
Identifying relationships: Hard, harder than many hard things

But NOT that Hard, When WE do it
Games with a purpose

• Get humans to give their solitaire time
  – Solve real hard computational problems
  – Image tagging, Identifying part of an image
  – Tag a tune, Squigl, Verbosity, and Matchin
  – Pioneered by Luis Von Ahn
• Relationship Identification Game

• leads to
• causes

Explosion

Traffic congestion
• How do you get comprehensive situational awareness by merging “human sensing” and “machine sensing”?
Research Challenge #4: Semantic Sensor Web

Semantic annotation of SWE

```xml
<swe:component rdfa:about="time_1"
  rdfa:instanceof="time:Instant">  
  <swe:Time rdfa:property="xs:date-time">
  2008-03-08T05:00:00
  </swe:Time>
</swe:component>

<swe:value name="satellite-data"
  rdfa:about="Dayton"
  rdfa:instanceof="geo:City">
  0011000111001111 ...
</swe:value>
```

Ontological Knowledge

space, time and theme
Semantically Annotated O&M

```xml
<swe:component name="time">
  <swe:Time definition="urn:ogc:def:phenomenon:time" uom="urn:ogc:def:unit:date-time">
    <sa:swe rdfa:about="?time" rdfa:instanceof="time:Instant">
      <sa:sml rdfa:property="xs:date-time"/>
    </sa:swe>
  </swe:Time>
</swe:component>

<swe:component name="measured_air_temperature">
    <sa:swe rdfa:about="?measured_air_temperature" rdfa:instanceof="senso:TemperatureObservation">
      <sa:sml rdfa:property="weather:fahrenheit"/>
      <sa:swe rdfa:rel="senso:occurred_when" resource="?time"/>
      <sa:swe rdfa:rel="senso:observed_by" resource="senso:buckeye_sensor"/>
    </sa:sml>
  </swe:Quantity>
</swe:component>

<swe:value name="weather-data">
  2008-03-08T05:00:00,29.1
</swe:value>
```
Semantic Sensor ML – Adding Ontological Metadata

Mike Botts, "SensorML and Sensor Web Enablement," Earth System Science Center, UAB Huntsville
Semantic Query

• Semantic Temporal Query

• Model-references from SML to OWL-Time ontology concepts provides the ability to perform semantic temporal queries
• Supported semantic query operators include:
  – **contains**: user-specified interval falls wholly within a sensor reading interval (also called *inside*)
  – **within**: sensor reading interval falls wholly within the user-specified interval (inverse of contains or inside)
  – **overlaps**: user-specified interval overlaps the sensor reading interval
• Example SPARQL query defining the temporal operator ‘within’

```sparql
SELECT ?interval
WHERE {
  ?interval time-entry:ends  ?e .
  ?b time-entry:inXSDDateTime ?b_datetime .
  ?e time-entry:inXSDDateTime ?e_datetime .

  FILTER (xsds:dateTime("2005-11-10T01:00:00.00") < xsds:dateTime(?b_datetime) &&
                      xsds:dateTime("2008-11-10T01:00:00.00") > xsds:dateTime(?e_datetime)) .
}
ORDER BY ASC(?b_datetime)
```
Kno.e.sis’ Semantic Sensor Web

Interface/Access

Semantic Sensor Observation Service

SOS Query
SML/O&M

52North
SPARQL Query Engine
Knowledge Base

Ontologies

Analysis
(Abductive Reasoning, Machine Learning, Statistical analysis, etc.)

Data Collection

Citizen-Sensor (Twitter, Flickr, etc.)
Wide-Area Sensors (IR, EO, RF, etc.)

Data feed
SML/O&M

RDF
Synthetic but realistic scenario

• an image taken from a raw satellite feed
Synthetic but realistic scenario

• an image taken by a camera phone with an associated label, “explosion.”
Synthetic but realistic scenario

• Textual messages (such as tweets) using STT analysis
Synthetic but realistic scenario

- Correlating to get
Create better views (smart mashups)
A few more things

• Use of background knowledge
• Event extraction from text
  – time and location extraction
    • Such information may not be present
    • Someone from Washington DC can tweet about Mumbai
• Scalable semantic analytics
  – Subgraph and pattern discovery
    • Meaningful subgraphs like relevant and interesting paths
    • Ranking paths
The Sum of the Parts

Spatio-Temporal analysis
  – Find out where and when
+ Thematic
  – What and how
+ Semantic Extraction from text, multimedia and sensor data
  - tags, time, location, concepts, events
+ Semantic models & background knowledge
  – Making better sense of STT
  – Integration
+ Semantic Sensor Web
  – The platform

= Situational Awareness
Domain Models

Search
Integration
Analysis
Discovery
Question
Answering
Situational
Awareness

Multimedia Content
and Web data

Metadata Extraction

Patterns / Inference / Reasoning

Meta data / Semantic Annotations

Metadata Extraction

Structured and Semi-structured data

Text

Multimedia Content and Web data

Sensor Data
Enriching Human Experience

- Recognition of objects (IOT) and models of object
- Understanding of objects and content
- Multimodal interfaces
- Multi(level) sensing and perception
- From keywords and entities to events and rich sets of relationships; spatio-temporal-thematic computing
- Models (ontologies, folkonomies, taxonomies, classification, nomenclature) – time, location, sensors, domain
- More powerful reasoning: paths, patterns, subgraphs that connect related things; deductive and abductive reasoning, ....
Online and offline worlds

• Computational abstractions to represent the physical world’s dynamic nature

• Merging online and offline activities
  – Connecting the physical world naturally with the online world

• What are natural operations on these abstractions?

• How do we detect these abstractions based on other abstractions and multimodal data sources?
Experience

Direct Observation of or Participation in Events as a basis of knowledge
Objects to Events

• If we move from this object mode to an event mode
  
  – A single user action or request or sensory observation could act as a cue for getting all (multi-modal) information associated with an event

  – If conditions change, systems could even modify their behavior to suit their changing view of the world

Today text is most prevalent, with increasing but disparate (non-integrated) image and video data, but human experience is event based (at higher levels of abstractions) formed based on multi-sensory, multi-perception (at lower level of abstraction) observations
Suppose that we create a Web in which

- Each node is an event or object
- Each node may be connected to other nodes using
  - Referential: similar to common links that refer to other related information.
  - Spatial and temporal relationships.
  - Causal: establishing causality among relationships.
  - Relational: giving similarity or any other relationship.
  - Semantic or Domain specific:
    - Familial
    - Professional
    - Genetics, …
Karthik Gomadamage

Attended Google IO Moscone Center, SFO May 28-29, 2008

Specio-temporal

Event

Causal

Domain Specific

Relational

is_advised_by

Ph.D Student

Assistant Professor

Professor

Researcher

Research Paper

Journal

Conference

Location

is_advised_by

is_advised_by

AmitSheth

Karthik Gomadamage

Kno.e.sis
However, today

Sensors capture and process uni-modal information. Bringing multiple modalities together is up to an application.

Object centric environments – sensors understand objects from data. Events and not objects lend to holistic views of an experience.

Multi-modal information effectively represents events.

Where is the Domain knowledge!?
• **Observation** is about capturing (or measuring) phenomena.

• **Perception** is about explaining the observations.

• When the human mind perceives what it observes
  – It uses what it already knows in addition to the context surrounding the observation
  – Cause-effect relationships play a vital role in how we reach conclusions
The diagram illustrates the integration of the **People Web** (human-centric) and the **Sensor Web** (machine-centric). The People Web encompasses Observation (senses), Communication (language), and Perception (cognition). On the other hand, the Sensor Web includes Observation (sensors), Communication (services), and Perception (analysis). The integration of these two webs highlights the crossover in areas such as communication and perception, where human-centric and machine-centric approaches converge.
Enhanced Experience  (humans & machines working in harmony)

Observation

Communication
Ability to share common communication

Perception
Semantics for shared conceptualization and interoperability between machine and human
Example

1. Sensors observe environmental phenomena and nearby vegetation.

2. Observation analysis determines potential situation and effects.

- Through abductive reasoning, observation analysis perceives a possible storm as the best explanation hypothesis for observed phenomena.

- Through predictive deductive reasoning, observation analysis determines the effect on the crops, including the potential for the poisoning of the soil from salt carried from the ocean in the wind.

- Through query against a knowledge base of the agriculture domain, observation analysis determines that the best remedy
  - for saline soil is to “leach” the soil with excess irrigation water in order to ‘push’ the salts below the crop root zone,
  - for sodic soil is to add gypsum before leaching.
1. Sensors observe environmental phenomena and nearby vegetation.

2. Observation analysis determines potential situation and effects.

3. System alerts nearby farmers of situation and possible remedy.

4. Farmer goes outside and looks at the sky and crops.

5. Farmer perceives high-winds and dark rain clouds over the ocean view and agrees with system perception.

6. Farmer calls children and neighbors to help take the necessary precautions to save the vegetables.
Sensing, Observation, Perception, Semantic, Social Experiential
Influential Works

- V. Bush, *As We May Think*, The Atlantic, July 1945. [*Memex, trail blazing*]
- V. Kashyap and A. Sheth, *Semantics-based information brokering*. Third ACM Intl Conf on Information and Knowledge Management (CIKM94), Nov 29 - Dec 02, 1994. ACM, New York, NY. [*semantics based query processing (involving multiple ontologies, context, semantic proximity) across a federated information sources across the Web*]
- Abowd, Mynatt, Rodden, *The Human Experience*, Pervasive computing, 2002. [*explores Mark Wisner’s original ubicomp vision*]
- AmitSheth, Sanjeev Thacker, and Shuchi Patel, Complex Relationship and Knowledge Discovery Support in the InfoQuilt System, VLDB Journal, 12 (1), May 2003, 2–27. [*complex semantic inter-domain (multi-ontology) relationships including causal relationships to enable human-assisted knowledge discovery and hypothesis testing over Web-accessible heterogeneous data*]
KNO.E.SIS as a case study of world class research based higher education environment

http://knoesis.org
Kno.e.sis Center Labs (3rd Floor, Joshi)

Amit Sheth
• Semantic Science Lab
• Semantic Web Lab
• Service Research Lab

TK Prasad
• Metadata and Languages Lab

Shaojun Wang
• Statistical Machine Learning

Pascal Hitzler
• Formal Semantics & Reasoning lab

Michael Raymer
• Bioinformatics Lab

Guozhu Dong
• Data Mining Lab

Keke Chen
• Data Intensive Analysis and Computing Lab
KNO.E.SIS MEMBERS – A SUBSET

Ajith
Web 2.0, Services

Karthik
Web 2.0, Services

Cory
Semantic Sensor Web

Meena
Casual text analysis

Topher
Social content analysis

Cartic
Relationship Extraction in biomedical text

Pablo
Relationship extraction, semantic browsing

Satya
Bio-Informatics, Provenance

Prateek

Matt
Geo-Spatial informatics
Exceptional students

- Six of the senior PhD students: 84 papers, 43 program committees, contributed to winning NIH and NSF grants.
- Successfully competed with two Stanford PhDs, 1000+ citations in 2 years of his graduation.
- “BTW, Meena is an absolute find. If all of your other students are as talented, you are very lucky. ... I’d definitely like to work with more interns of her caliber, ... ” [Dr. Kevin Haas, Director of Search at Yahoo!]
- “It has been a few years since I visited Dayton (Wright AFB). However, it is clear that Wright State has transformed itself. Congratulations on your success with the Knoesis Center.” [Dr. AlpersCaglayan – looking to hire Kno.e.sis grads]
Funding, Collaboration, etc

- UGA, Stanford, CCHMC, SAIC, HP, IBM, Yahoo!
- NIH, NSF, AFRL-HE, AFRL-Sensor, HP, IBM, Microsoft, Google
- 70% Federal, 19% State, 11% Industry
- Students intern at the best Industry labs & national labs
- Graduates very successful

• Ramesh Jain, Toward EventWeb. IEEE Distributed Systems Online 8, 9, Sep. 2007. [a web of temporally related events… informational attributes such as experiential data in the form of audio, images, and video can be associated with the events]


Other Closely Related publications


• Amit Sheth and Matthew Perry, “Traveling the Semantic Web through Space,” Time and Theme,” IEEE Internet Computing, 12, (no.2), February/March 2008, pp.81-86.

Interested in more background?

- **Semantics-Empowered Social Computing**
- **Semantic Sensor Web**
- **Traveling the Semantic Web through Space, Theme and Time**
- **Relationship Web: Blazing Semantic Trails between Web Resources**
- **Text Mining, Workflow Management, Semantic Web Services, Cloud Computing with application to healthcare, biomedicine, energy**

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Significant Infrastructure

VERITAS

Whole-Body Laser Range Scanner

stereoscopic 3D visualization

NMR

AVL