Research Directions in Requirements Engineering

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Outline

- What is RE?
  - Why is RE difficult?
- RE State of the Art
- Research Strategies
- RE Research Hotspots
- Recommendations

What is Requirements Engineering?

Requirements engineering is the branch of software engineering concerned with the *real-world goals for, functions of, and constraints on software systems.*

It is also concerned with the *relationship of these factors* to precise specifications of software behavior, and to *their evolution over time* and across software families.

[Zave 83]

Why is RE Difficult?

- RE faces complementary challenges from those faced by the rest of SE community
- Different types of artifacts
  - Downstream SE works in solution space
  - RE works in problem space

Why is RE Difficult?

Issues	Downstream SE	RE
Domain	Solution space	Problem space
Starting point	Specified by requirements	
Alternatives to consider	Constrained by requirements, platform, acceptance, priorities, system boundaries	
Stakeholders	Technical, more homogeneous	
Artifacts	Models of SW	
Resources	Majority of resources	

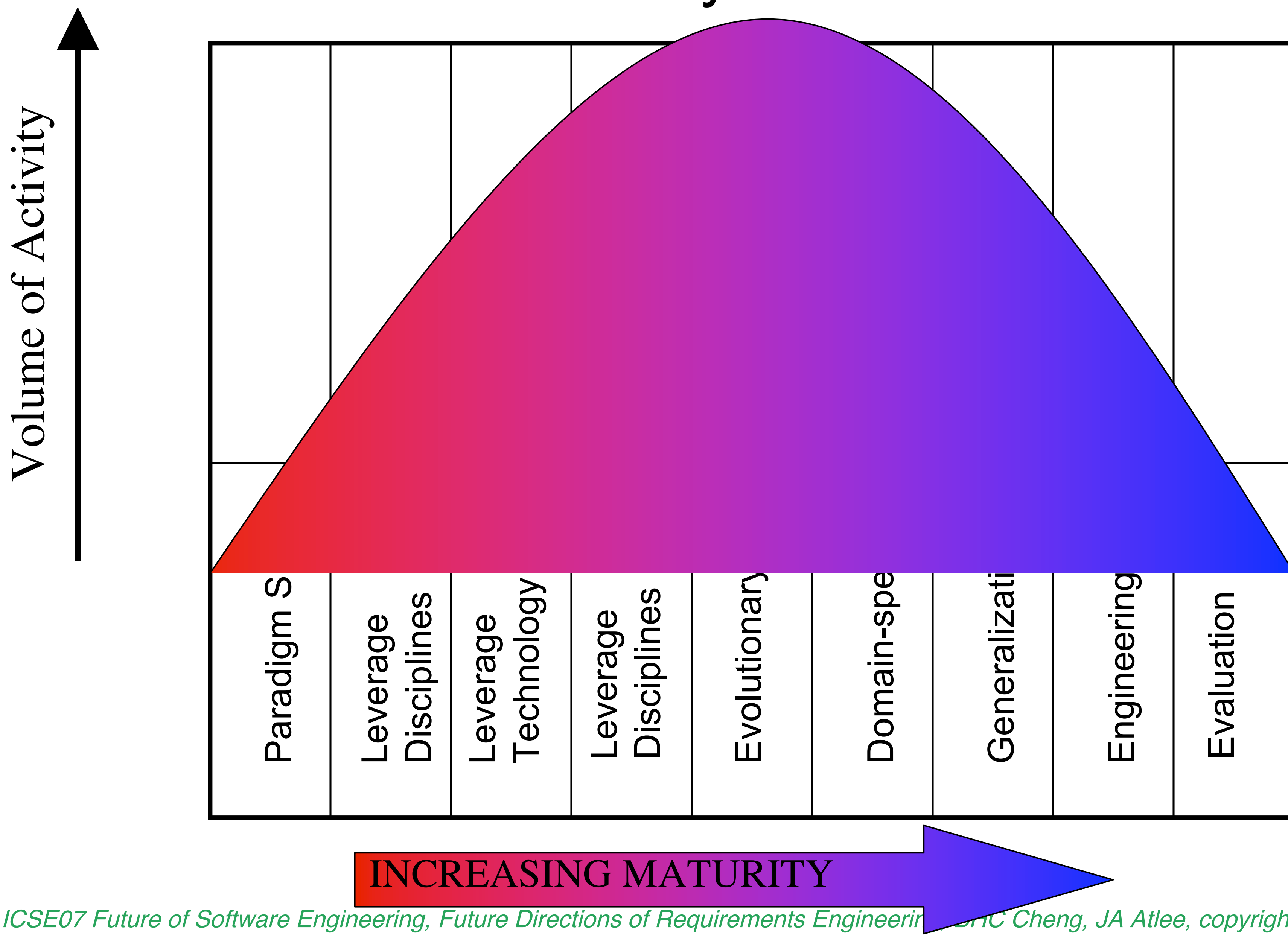
Research Strategies

INCREASING MATURITY

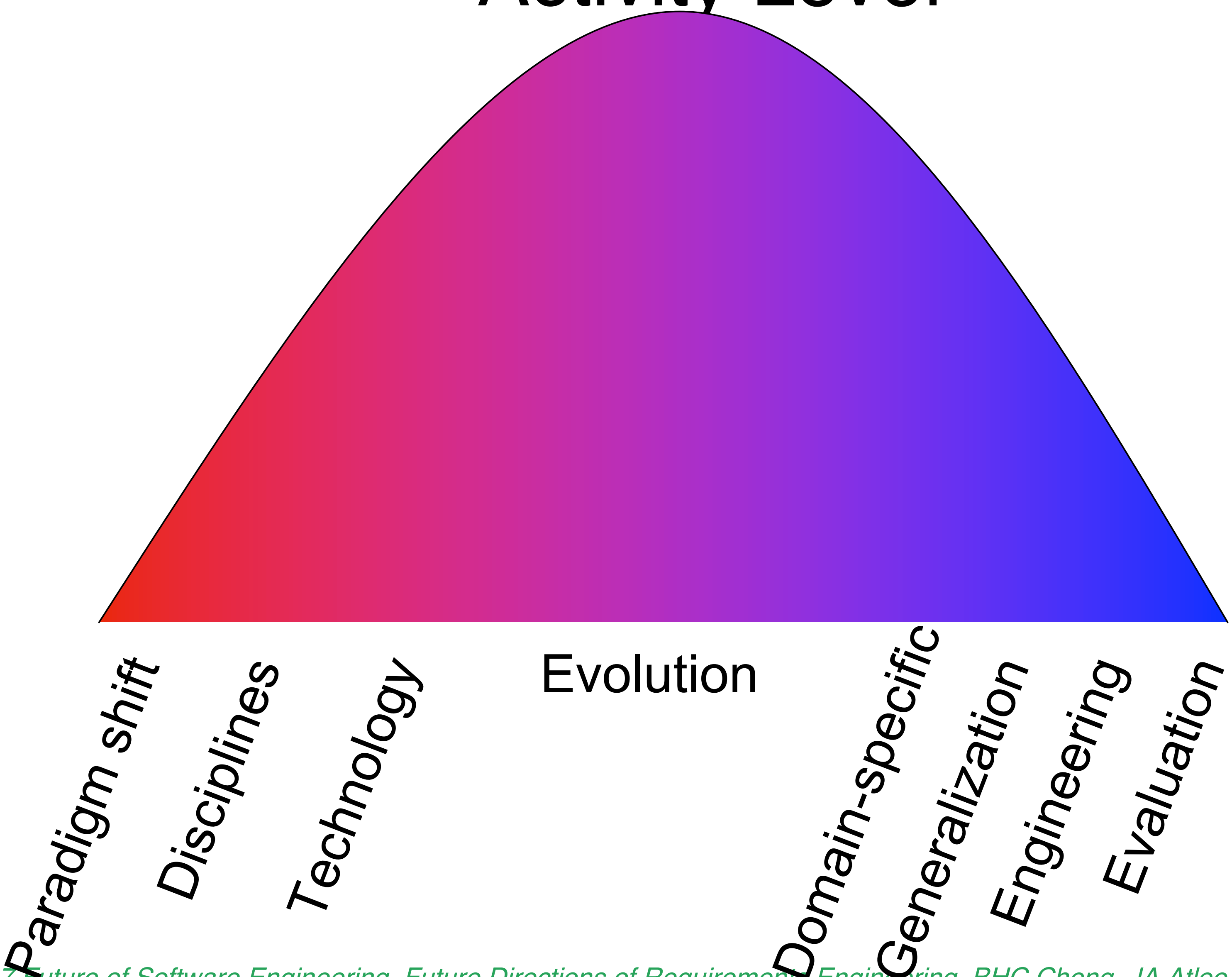
Strategy	Definition
Paradigm Shift	
Leverage other disciplines	
Leverage technology	
Evolutionary	
Domain-specific	
Generalization	
Engineering	
Evaluation	

[Shaw02, Redwine and Riddle 85, Basili93]

Research Strategies
Activity Level



Research Strategies
Activity Level



Matrix of State of the Art

	Research Contributions		
	Notations	Methodologies,	Analysis, Tools
Elicitation			
Modeling			
Reqts Analysis			
V&V			
Reqs Mgmt			

Elicitation: Activities that enable the understanding of the goals, objectives, and motives for building a system.

Modeling: Abstract representations of system’s goals, objectives, motives, and requirements

Reqs Mgmt: Managing requirements during construction and evolution
- Identifying and documenting traceability links
- Integration of requirements of different ages

Matrix of State of the Art

	Research Contributions		
	Notations	Methodologies, Patterns, Strategies	Analysis, Tools
Elicitation			
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Reqs			

Notations	Methodologies, Patterns, Strategies	Analysis, Tools
Notation Semantics [117,122,161,135]	RE Reference model [75,76,128]	Model merging [145,163]
Logics [52]	Model elaboration [167]	Model synthesis [4,41,107,166,179]
Behavioral models [90,165]	Viewpoints [125,153]	Model composition [79]
Domain descriptions [12]	Patterns [56,87,97,169]	
Object models [86]	Modeling facilitators [7,34,95,126]	
	Formalization heuristics [20,68]	
	Methodologies [16]	

Hot Spots

- Definition: areas with pressing needs given anticipated challenges posed by emerging systems (e.g., scale, security, tolerance, tighter integration between system and environment)
- <u>How we selected specific hot spots:</u>
  - Extensions to the State of the Art:
    - Based on "gaps" in matrix and research strategies
    - Internal factors (push on boundaries)
  - Defining New State of the Art:
    - External factors (from stakeholders from industry, govt, users)
    - Emerging systems
    - Proactive (part of problem solving team)
      - identify promising solutions
      - define the leading edge (or be reactive)

Hot Spots Impact

Problems	Requirements Contributions		
	Notations	Methodologies, Patterns, Strategies	Analyses, Tools
Elicitation	Goals [21, 170] Policies [20] Scenarios [1, 35, 49] Agents [106, 180] Anti-models [155, 164, 171] [ ][ ] Nonfunctional requirements [31, 79]	Identifying stakeholders [150] Metaphors [130, 133] Persona [10, 38] Contextual requirements [36, 159] Inventing requirements [72, 115]	Animation [82, 113, 168] Prototyping [51] Simulation [162] Invariant generation [91]
Modeling	Object models [86] Behavioral models [90, 165] Domain descriptions [12] [ ][ ] Logics [52] Notation Semantics [117, 122, 161, 135]	RE reference model [75, 76, 128] Model elaboration [167] Viewpoints [125, 153] Patterns [56, 87, 97, 169] Modeling facilitators [7, 34, 95, 126] Formal Methoc	Model merging [145, 163] Model synthesis [4, 41, 107, 166, 179] Model composition [79]
		Negoti Alignin Conflic	Variability analysis [74, 108, 109] Requirements selection [137, 158]
Validation & Verification	Property languages [15, 105] Model formalisms [24, 53] Object models [86] Sjkfoafwienvoania Akejhvnlaweuhvb	Ahksjhfksjhfskh Pjshflkjshdsfjh	Simulation [162] Animation [82, 113, 168] Invariant generation [91] Consistency checking [60, 81, 120] Inspections [62, 129] Model checking [29, 57, 157] Model satisfiability [86]
Requirements Management	Variability modeling [23, 40, 138, 148]	Scenario management [3] Feature management [176]	Traceability [33, 80, 144, 149] Impact analysis [101] Stability analysis [25]

Extensions to State of Art:

- Methodologies, Patterns, Tools
- Reuse
- Effectiveness of RE Techniques

New State of the Art

Matrix of State of the Art

	RE Problems Key here:	Requirements Contributions		
		Notation	Methodologies, patterns, strategies	Analysis, Tools
RE problem	Elicitation	Human strategies mature; evolutionary for creating new notations for elicited reqts; ever-increasing (higher) level of abstraction (reqts-> goals-> policies)	empirical	Leverage technology video con
	Modeling	Evolutionary; specialization (e.g., viz: Drawing HCI, graphics)	Engineering: codification of experience	Evolutionary; generalizatio (model transformatio omposition --> understand composition.
	Requirements	NA	Leverage other	Blow up: lots

Extensions to State of Art

- Methodologies, Patterns, Tools
  - Need more engineering-oriented research to
    - integrate current techniques and
    - Make more widely available, applicable
  - Requirements Reuse (e.g., patterns)
    - Within a domain
    - Across domains
- Effectiveness of RE Technologies
  - Need more evaluation-oriented research
    - Demonstrate utility of current RE techniques on industrial-strength problems
  - Also need comparisons of similar techniques
    - Provide guidance as to when one approach is more appropriate

New State of the Art

- Motivated by anticipated needs
  - External factors (from stakeholders from industry, govt, users)
  - Emerging systems
- Research Challenges:
  - Scale
  - Toleran
  - Self-Man
  - Cyberphys
  - Security

Scale

New Scale

- Definition: new orders of magnitude increase in scale *[ULS Report, SEI 2006]*
  - Size
  - Heterogeneity
  - Decentralized elements
  - Complexity (decision logic)
- Examples: (of the future)

New Scale

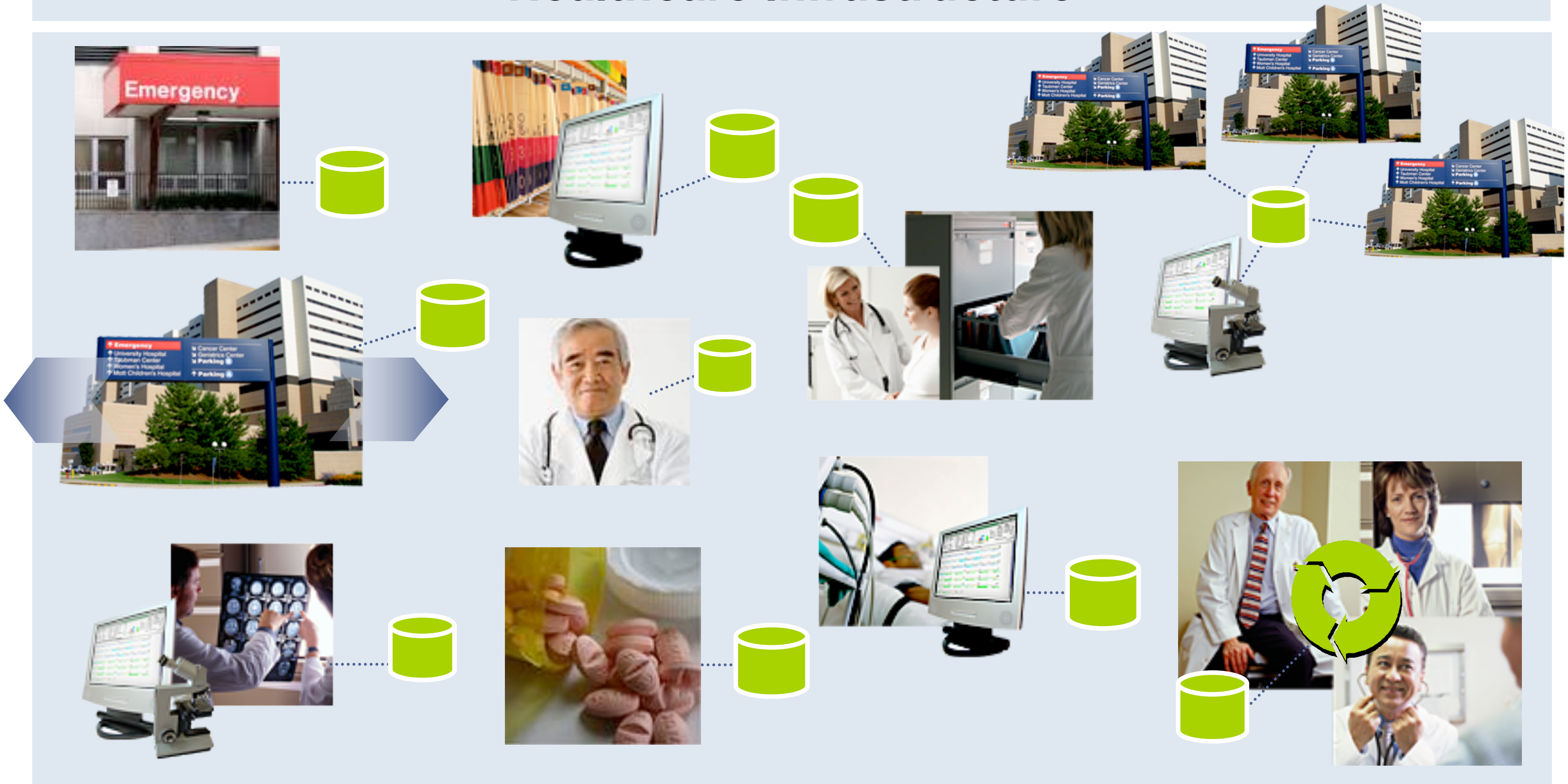
Example:

Intelligent Transportation and Vehicle Systems

New Scale

Ultra-Large Scale SW-Intensive Systems

Healthcare Infrastructure

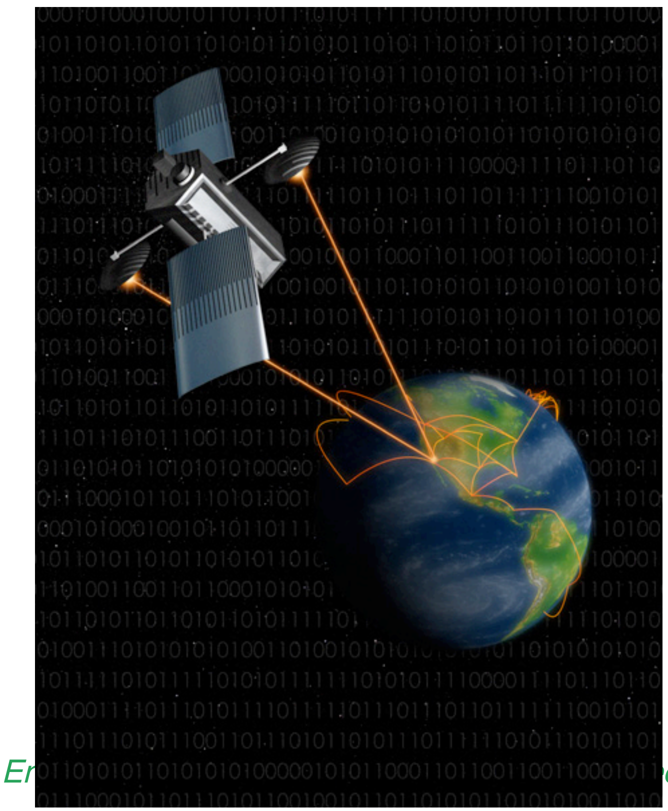


New Scale

- Definition: new orders of magnitude increase in scale
  - Size (e.g., thousands of sensors, platforms)
  - Heterogeneity
  - Decentralized elements
  - Complexity (decision logic)
- Example: ITS and IVS
- RE Challenges:
  - Modeling, abstraction, analysis techniques to handle new notions of large scale.
  - Managing requirements with uncertainty in data, processing, platforms
  - Detecting/resolving feature interactions

Self-Managing Systems

- Definition: software-based system is aware of its context and must react and adapt to changes in the environment or requirements *[Kramer and Magee, FoSE07]*
- Examples:



Self-Managing Systems

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- Examples:
- RE Challenges:
  - Determining when adaptation is needed
  - Supporting changing requirements
  - Gaining assurance for adaptive systems
    - Identify assurance criteria
    - Reasoning technology for adaptive systems
  - Run-time monitoring of system and environment wrt current requirements

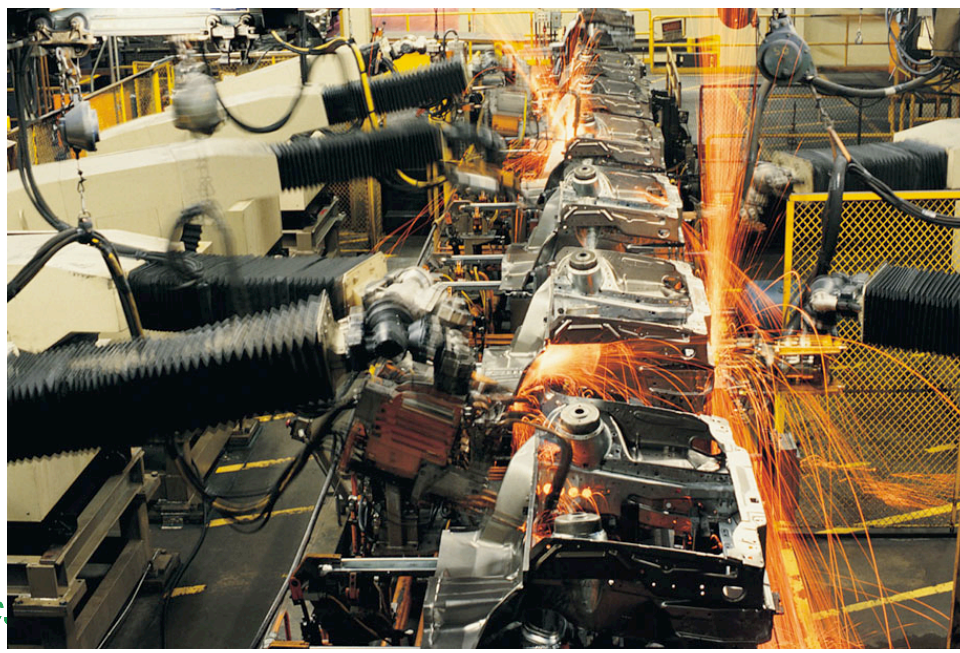
Tolerance

- Definition of sufficient correctness
  - *"The degree to which a system must be dependable in order to serve the purpose its user intends, and to do so well enough to satisfy the current needs and expectations of those users"* [Shaw WOSS02].
- RE Challenges
  - Size of systems will make it impractical to have complete, consistent, and stable requirements -- need to settle for "healthful systems"
  - Requirements for fault tolerance (cannot wait to address FT at design/implementation)
  - Negative requirements (e.g., unhealthy conditions to avoid)
  - Requirements for diagnostic and recovery mechanisms

Cyberphysical

- Definition: Software seamlessly integrated with environment. *[Schaefer and Wehrheim, FoSE07]*
  - Computing and communication tightly coupled with monitoring and control of physical entities in environment
- Examples:

Automated Manufacturing



Handheld/Wearable Computing

Cyberphysical

- Definition: Software seamlessly integrated with environment. *[Schaefer and Wehrheim, FoSE07]*
  - Computing and communication tightly coupled with monitoring and control of physical entities in environment
- Examples:
- RE Challenges:
  - Need to model environment (not discrete)
  - Hybrid models (continuous and discrete systems interacting)
  - Unpredictable environmental factors (e.g., humans)
  - Uncertainty aspects:
    - What (when) to monitor,
    - Reacting to dated conditions (delayed information)
    - Noise in sensor data
    - Interpreting the data (SW state or environmental conditions)

Security

- Definition:
  - "A computer is ***secure*** if you can depend on it and its software to behave as you expect (intend)."
  - '***Trust*** describes our level of confidence that a computer system will behave as expected.' (intended)

[Garfinkel & Spafford, Kasten]

- Examples:
  - Healthcare Infrastructure
  - Intelligent Transportation Systems

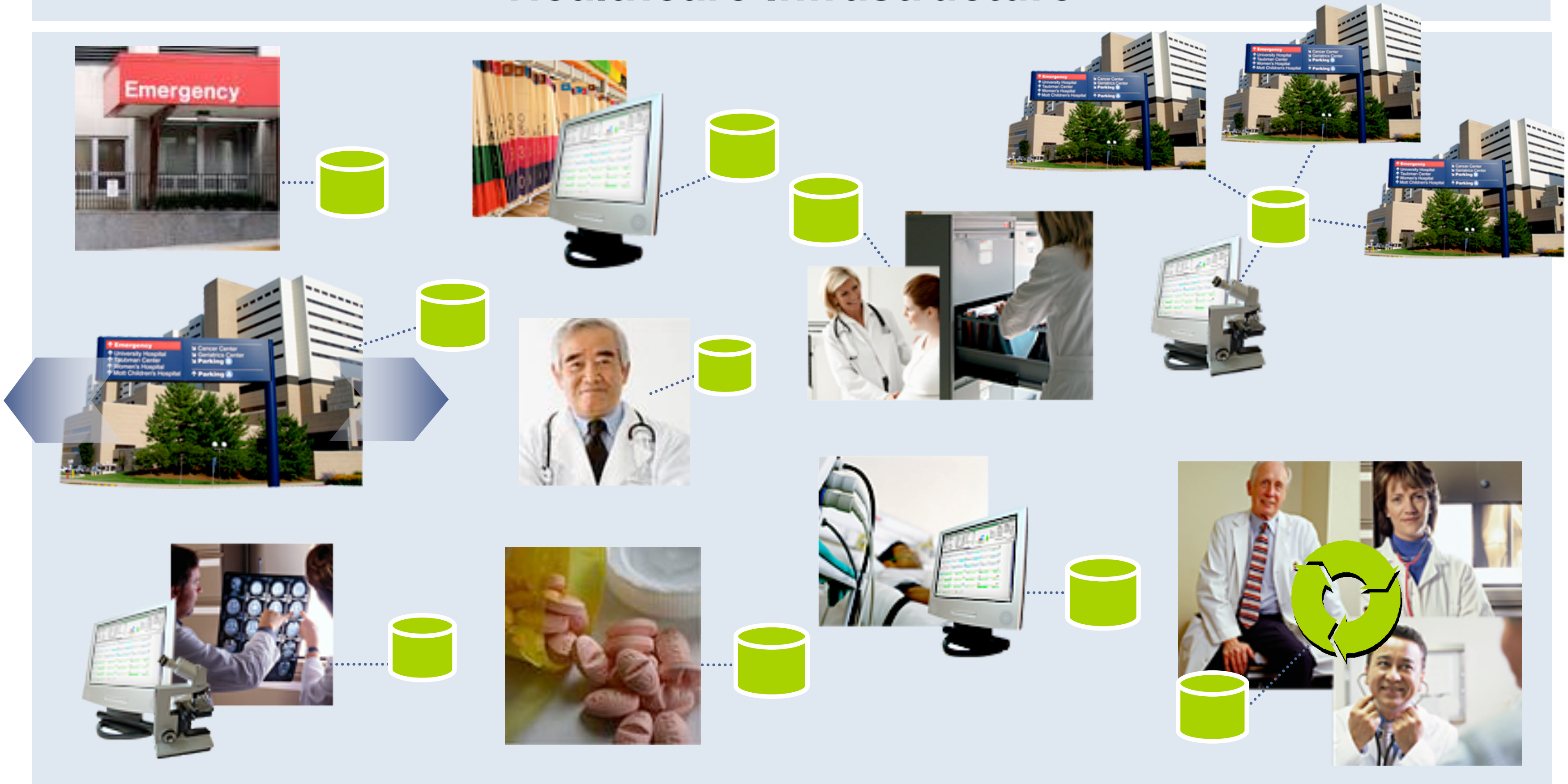
MICHIGAN STATE UNIVERSITY

ULS of the Future

University of Waterloo

Numerous Security Concerns

Healthcare Infrastructure



ULS of the Future

Numerous security concerns

Intelligent Transportation and Vehicle Systems

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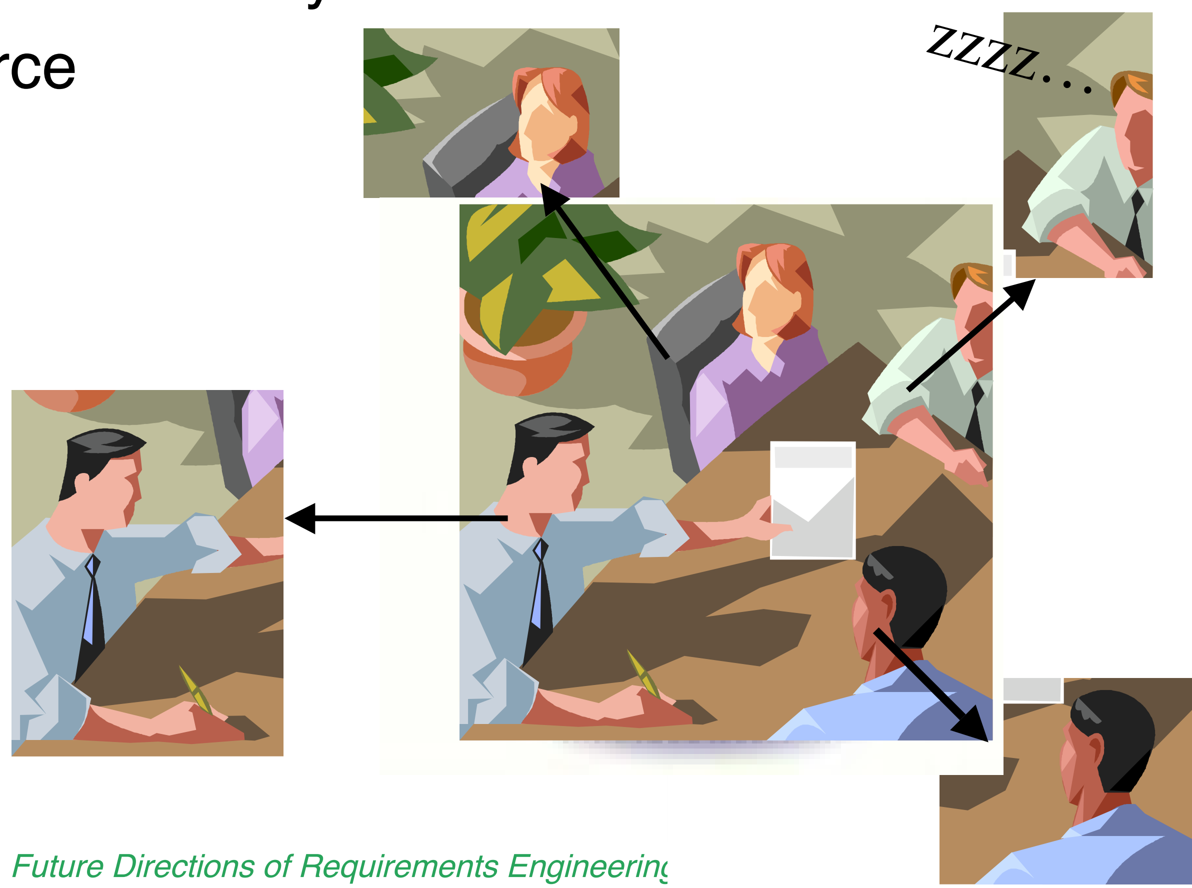
[Garfinkel & Spafford, Kasten]

- Examples:
- RE Challenges:
  - Modeling the environment
    - Need for complete (threat) models
  - Malicious entities exist
  - Notations and methodologies
    - Structuring, modeling, and reasoning about security policies
  - Monitoring for security requirements adherence
  - Tools for modeling and analyzing security requirements

Globalization

- Definition: globally distributed development teams [Herbsleb, FoSE07]
- Motivation:
  – Exploit a 24-hour work day
  – Global work force



Globalization

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  [Herbsleb, FoSE07]
- Motivation:
  - Exploit a 24-hour work day
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- RE Challenges:
  - RE documentation must support distributed downstream development activities (design, coding, testing)
  - Communication support in a distributed environment:
    - Requirements elicitation, modeling, negotiation
    - Team management (geographical, time zone, culture, language)

Recommendations

RESEARCHERS

Extensions to State of Art

- ***Engineering/integrating RE Techniques***
- ***Apply to industrial-strength data***
- ***Comparative studies***

- ***Integrate with downstream SE research***
- ***Training the next generation***

INDUSTRY/PRACTITIONERS

External factors pose new challenges

- **New computing needs**
- **New application domain needs**
- **New users**
- **Leverage new technology**

Defining New State of Art

- ***Looking for paradigm shifts for emerging systems and challenges***
- ***New modeling, analysis, abstraction techniques***

New Considerations

- **Scale**
- **Assurance**
- **Distributed Control**
- **Autonomic Behavior**

Recommendations

Researchers

Extensions to State of Art

- *Engineering/integrating RE Techniques*
- *Apply to industrial-strength data*

- *Integrate with ... research*
- *Training the next generation*

Collaborative Partnerships

- Collaborative research efforts
- Collective identification and definition of RE research challenges
- Sanitized industrial-strength data
- Repositories of RE-related artifacts
- Evaluation of research techniques

Industry and Practitioners

External factors pose new challenges
- New computing needs
- ... domain needs
- New users
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Defining New ...
- *Looking for paradigm shifts for emerging systems and challenges*
- *New modeling, analysis, abstraction techniques*

... Considerations
- Scale
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- Distributed Control
- Autonomic Behavior

[Whitehead, FoSE07, Rombach & Achatz, FoSE07]

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Take home message…

Researchers

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- *Compar…*
- *Integrate wi… research*
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