Welcome to SENG 480B / CSC 485A / CSC 586A Self-Adaptive and Self-Managing Systems

Dr. Hausi A. Müller
Professor and Associate Dean Research
Department of Computer Science
University of Victoria

http://courses.seng.uvic.ca/courses/2015/summer/seng/480a
http://courses.seng.uvic.ca/courses/2015/summer/csc/485a
http://courses.seng.uvic.ca/courses/2015/summer/csc/586a

1

Outstanding TAs

Lorena Nina Ron

2

Announcements

- Monday, May 18
  - Victoria Day — no class
- Thursday, May 21
  - Lorena Castañeda — ULS
- Monday, May 25
  - Lorena Castañeda — ULS
- Friday, May 29
  - A1 due
  - Email addresses for Part III posted
  - URL

iRobot's new drone is a rock-steady flyer

Reading Assignments

- ULS Book Section 1-3 on-line at
  - http://www.sei.cmu.edu/uls/the_report.html
- Murray (Ed.): Control in an Information Rich World Report of the Panel on Future Directions in Control, Dynamics, and Systems, SIAM (2003)
  - Chapters 1 & 2
  - http://www.cds.caltech.edu/~murray/cdspanel/report/cdspanel-15aug02.pdf

4

Groups for A1 Part III

G1	Ernest Aaron, Adel Adil, Louk Veenis
G2	Marysi Arciniegas Mendez, Navdeep Bahia, Richard Wagner
G3	Simar Arora, Miles Barr, Evan Wilde
G4	Fei Chen, David Bayly, Elliot Wyman
G5	Shu Chen, Jonathan Bowen, Gueorgui Zahariev
G6	Harsh Dawar, Joshua Braidek, Zhenyu Zhang
G7	Erkan Ersan, Po An Chen, Pufan Zheng
G8	Maria Ferman Guerra, Jason Cho, Zhanxue Zhu
G9	Khushboo Gandhi, Sebastian Craig, Mohammad Bin Abdulsalam
G10	Harneet Kaur, Yongjun Xu, Timothy Dalton,
G11	Francis Harrison, Meric Demiriz, Jorge Conde Gomez Llanos
G12	Stephan Heinemann, Sean Debroini, Tory Borsboom-Hanson
G13	Harshit Jain, Rodney Celera, John Cox
G14	Sumit Kadyan, Alice Gibbons, Fraser DeLisle
G15	Navpreet Kaur, Zhuoli Xiao, Adnan Duale
G16	Parminder Kaur, Abhinandan Jagdev, Dustin Faulkner
G17	Waseem Khan, Anthony Kohan, Xiaotian Li
G18	Nishant Khanna, Patrick Lavoie, Connor McConkey
G19	Akshay Khot, Junru Yang, Ian Leslie
G20	Carlene LeBeuf, Siqi Li, Darren Prince
G21	Ye Liang, Ran Wei, Bowen Liu, Simon Taft
G22	Junnan Lu, Colum McClay, Jiashu Xiong
G23	Adithya Rathakrishnan, MacKay McGillivray, Shuo Yen Yu
G24	Arturo Reyes Lopez, Brenda McPhail, Mohammed Nader Zuhri Yafi
G25	Babak Tootoonchi, Daniel Oon, Muhammad Zubair
G26	Sam Wang, Hernan Rossi, Samuel Navarrete
G27	Stephan Wasylishen, Victoria Sahle, Sahibdeep Sran

Email will be disseminated shortly

If you are uncomfortable about disseminating your email to the class list send me a note

5

Terms to study on the web

- Internet of things
- Industrial Internet (GE)
- Cyber-physical systems
- Ultra-large-scale systems
- Digital ecosystem
- Wearable computers
- The age of context
- Context awareness
- Situational awareness
- Big data
- Big data analytics
- Ubiquitous computing
- Pervasive computing
- Cloud computing
- Green computing
- Sensors and actuators
- Smart systems
- Google driverless car
- Google glass
- Microsoft Hololens
- iRobot
- Quadcopters

6

Adapt on the Fly—at Runtime

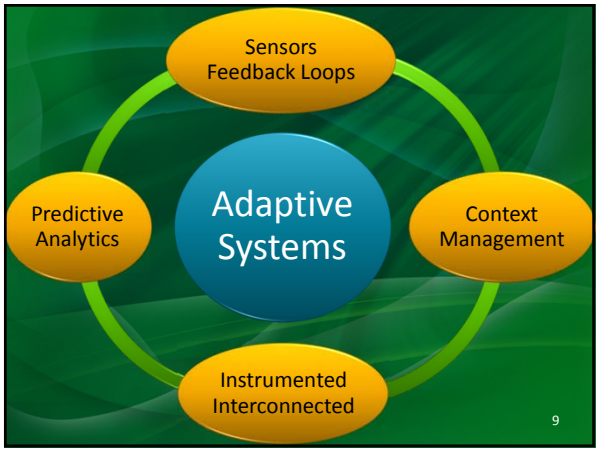
- Sensors give us the ability to monitor things
- Depending on the measures, things can adapt via actuator

7

Smarter System Characteristics

Smarter systems adapt at runtime

8



9

We need a new discipline

Software Engineering @ Runtime

10

Software Engineering @ Runtime

- Requirements@runtime
- Models@runtime
- Monitoring@runtime
- V&V@runtime
- Adaptation@runtime
- Analysis@runtime
- CM@runtime
- Assurance@runtime

- Profound impact on SE and CS
- Rethink software design and evolution for highly adaptive software systems
- Feedback loops and control theory are key

Boundary between development-time and run-time is disappearing

- Baresi, Ghezzi: The disappearing boundary between development-time and run-time. In: *FSE/SDP Workshop on Future of Software Engineering Research (FoSER 2010)*, pp. 17-22 (2010)

11

Requirements @ Runtime

- **From** satisfaction of requirements through traditional, top-down engineering

The system shall do this … but it may do this … … as long as it does this.

- **To** satisfaction of requirements by regulation of complex, decentralized systems

How much environment uncertainty can we afford? What's the cost? What benefits do we accrue by accommodating context uncertainty?

12

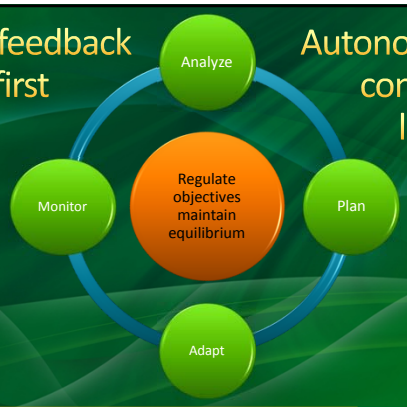
Models @ Run.time

- Runtime model representation and management
- Models @ Run.time need reflection
- Goal models for NF requirements
- Runtime verification of statecharts
- Dynamic context models
- UML behavioral models at runtime
- Applying MDE tools at runtime
- GUI runtime adaptation models
- Model synchronization
- Models for security analysis

- Bencomo: Workshop Series on Models@run-time, http://www.comp.lancs.ac.uk/~bencomo/WorkshopMRT.html
- Bencomo: Workshop Series on Requirements@run.time, http://www.comp.lancs.ac.uk/~bencomo/RRT/
- Dagstuhl Seminar: Models@run.time, 2011 http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=11481

Make feedback loops first class

Autonomic control loop



- Müller, Pezzè, Shaw: Visibility of control in adaptive systems, *Proc. Second Int. Workshop on Ultra-Large-Scale Software-Intensive Systems (ULSSIS 2008)*, pp. 23-26 (2008)

14

Assurance @ Runtime
Make V&V @ Runtime First Class

- V&V ensures that software satisfies requirements and quality attributes
- Runtime V&V ensures proper system operation during adaptation
- Certifiable V&V methods are critical for smart systems


United States Air Force
Chief Scientist (AF/ST)

Report on

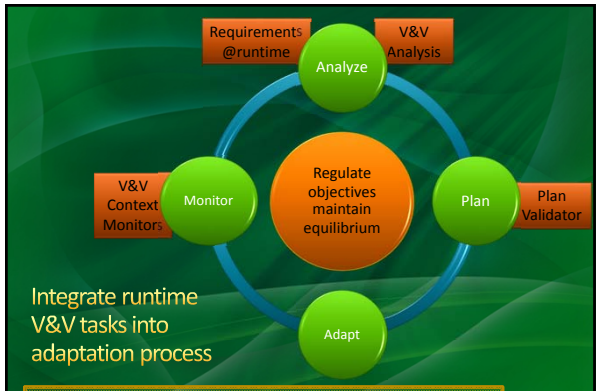
Technology Horizons

A Vision for Air Force Science & Technology During 2010-2030

Volume 1
AF/ST-TR-10-01-PR
15 May 2010

- Dahm: Technology Horizons: A Vision for Air Force Science & Technology During 2010-2030. TR USAF (2010)
- Villegas, et al.: A Framework for Evaluating Quality-Driven Self-Adaptive Software Systems, In: *Proc. 6th ACM/IEEE Software Engineering for Adaptive and Self-Managing Systems (SEAMS 2011)*, pp. 80-89 (2011)
- Tamura, Villegas, Müller, et al.: Towards practical runtime verification and validation of self-adaptive software systems. In: de Lemos, Giese, Müller, Shaw (Eds.), *Software Engineering for SAS*, Springer (2012)

15



Integrate runtime V&V tasks into adaptation process

- Tamura, Villegas, Müller, et al.: Towards practical runtime verification and validation of self-adaptive software systems. In: de Lemos, Giese, Müller, Shaw (Eds.), *Software Engineering for SAS*, Springer (2012)

16

Control Science

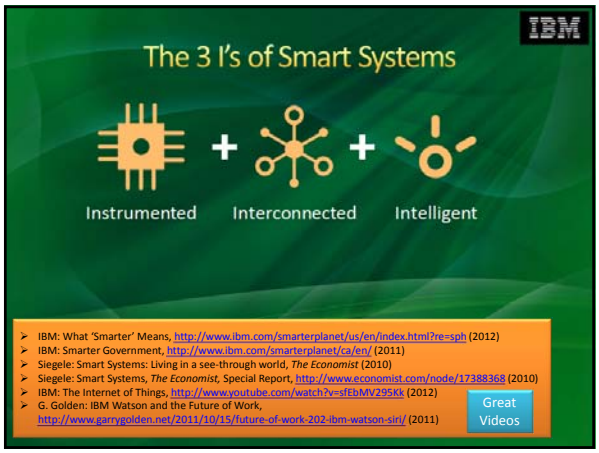
Control science can be defined as a systematic way to study certifiable V&V methods and tools to allow humans to trust decisions made by self-adaptive smart systems.

17

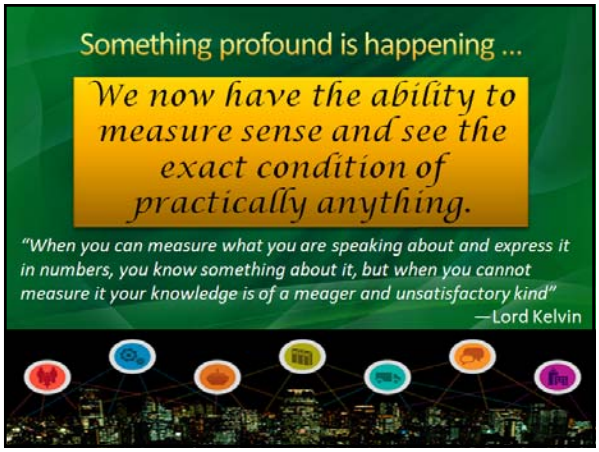
Cyber-Physical Systems

Convergence of Computing, Communications, and Control

- CPS encompass
  - computational and physical components
  - seamlessly integrated and closely interacting
  - sense the changing state of the real world
- CPS complexity
  - numerous spatial and temporal scales
  - controlling computational and physical components
  - highly networked communications
- CPS interconnected capabilities
  - integrated networking
  - computing
  - controlling
  - sensing and actuation
- CPS impact
  - societal impact is enormous
  - virtually every engineered system is affected by advances in these interconnected capabilities
- CPS applications
  - expected to be more transformative than the IT revolution of the past three decades
- Related terms — subsystems of CPS
  - Internet of things (IoT)
  - Industrial Internet (II)
  - Systems for a smarter planet (smart cities, smart grid, smart cars, smart everything)


IBM
The 3 I's of Smart Systems
Instrumented
Interconnected
Intelligent
IBM: What 'Smarter' Means, http://www.ibm.com/smarterplanet/us/en/index.html?re=sph (2012)
IBM: Smarter Government, http://www.ibm.com/smarterplanet/ca/en/ (2011)
Siegele: Smart Systems: Living in a see-through world, The Economist (2010)
Siegele: Smart Systems, The Economist, Special Report, http://www.economist.com/node/17388368 (2010)
IBM: The Internet of Things, http://www.youtube.com/watch?v=sfEbMV295Kk (2012)
G. Golden: IBM Watson and the Future of Work, http://www.garrygolden.net/2011/10/15/future-of-work-202-ibm-watson-siri/ (2011)
Great Videos


IBM
Something profound is happening ...
Instrumented
We now have the ability to measure sense and see the exact condition of practically anything.
Interconnected
People, systems, and objects can communicate and interact with each other in entirely new ways.
Intelligent
We can respond to changes quickly and accurately and get better results by predicting and optimizing for future events.


Something profound is happening ...
We now have the ability to measure sense and see the exact condition of practically anything.
"When you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it your knowledge is of a meager and unsatisfactory kind"
—Lord Kelvin


Something profound is happening ...
Over the past three years people have given up their location and time privacy —willingly


Something profound is happening ...
The Smart Systems Revolution
Instrumented
Interconnected
Intelligent
Smart devices
Sensors


Confluence of Sensors, Networks, Devices, Clouds, and Apps
Confluence 2013

IBM Initiative
Smarter Systems for a Smarter Planet

The world is getting smarter
More instrumented, interconnected, intelligent

Smart traffic systems | Intelligent oil field technologies | Smart food systems | Smart healthcare | Smart energy grids | Smart retail

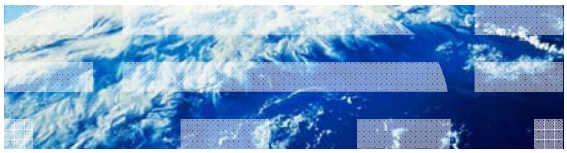
Smart water management | Smart supply chains | Smart countries | Smart weather | Smart regions | Smart cities

---

Presenter's name
Title
email
date

IBM

Let's Build a Smarter Planet:
Green Infrastructure



IBM

Reality of a globally integrated business world.

- Economic downturn requires doing more with the same and using self funding projects.
- Business and organizations need to use less energy and water.
- Use electricity required for day-to-day operations as efficiently as possible.
- Sustainability has emerged as a new business imperative.

These issues are interwoven.

IBM

The need for an energy efficient infrastructure is clear.

35%
IT energy expense is expected to increase 35% in the next four years.

8 in 10
More than 80% of CEOs expect climate change regulation 5 years.

40%
Buildings account for 40% of worldwide energy consumption.

Mandate for change is strong.

Inefficiencies in current infrastructure	No accurate measure of energy use enterprise wide.	Facilities management is not integrated.
		
▪ Reduce energy costs up to 40% a year. ▪ Extend the life of IT and defer CAPX and OPEX cost.	▪ Document and benchmark current energy metrics. ▪ Enable readiness for rapidly emerging regulatory environment.	▪ Impacts more than 50% of your energy expense. ▪ Leverage asset management for tax, utility, stimulus incentives.

IBM

Green Infrastructure is an instrumented and interconnected system enabled by intelligent energy management.

IT Equipment

- Energy efficient hardware
- Virtualization and consolidation
- Active energy management
- Tiered storage

Applications and Data

- Lifecycle management, retention, archiving of data
- Optimization of application servers
- Application performance monitoring
- Data deduplication, compression and clean up

Data Center

- Accurate thermal and energy usage assessments
- Extend life of existing infrastructure
- Rationalize infrastructures across company
- Design flexibility into new data center infrastructure

Real estate and facilities

- Trend analysis and building maintenance diagnostics
- Building management systems integration
- Process management automation
- Dashboard reporting

Energy Management

- IT and Infrastructure interfaces
- Threshold controls
- Optimize assets for energy efficiency
- Track and verify energy efficiency

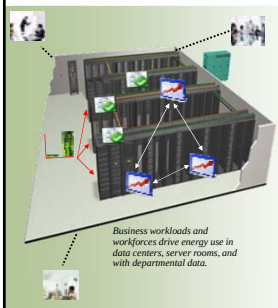
IBM

IT Equipment:
Virtualization and consolidation boost utilization.

Server Virtualization	Storage Virtualization	Client Virtualization
		
Up to 30-70% TCO savings	**Up to 25% less capacity needed**	**Up to 40% overall TCO savings**
▪ Up to 33-50% floor space and facility costs. ▪ 33-70% hardware costs. ▪ Up to 50% maintenance costs. ▪ Up to 33% support costs.	▪ Up to $50,000 power savings per 1,000TBs of installed storage. ▪ Up to 60% migration costs savings. ▪ Up to 300% increase in utilization	▪ Up to 45% power savings. ▪ Up to 90% deskside support. ▪ Up to 50% on helpdesk. ▪ Up to 75% in security and user administration.

IBM

Applications and Data :
Improve operations and environmental impact.



Business workloads and workforces drive energy use in data centers, server rooms, and with departmental data.

Measure and **control** energy usage of applications, manage storage infrastructure for efficiency.

Tivoli software

Lower energy cost of applications with application level **virtualization** that increases utilization while meeting transaction level service level agreements.

WebSphere software

Intelligent management of information via **de-duplication, compression** and hierarchical storage to reduce both storage and energy costs.

Information Management

Optimize application design and deployment architecture for reduced resource and energy needs.

Rational software

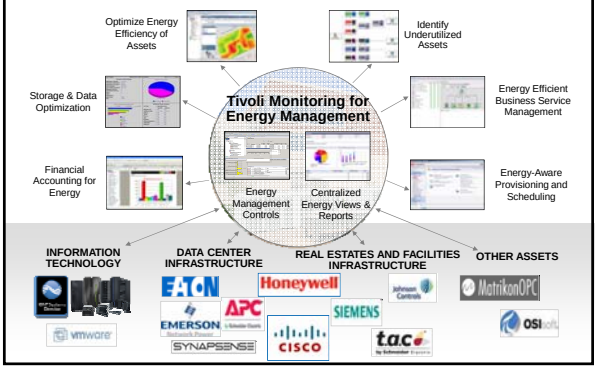
IBM

Data Center:
Efficient growth with modular designs.

Scalable modular data center.	Enterprise modular data center.	Portable modular data center.	High density zone.
			
Up to 20% less than traditional designs.	**Defer 40-50% of capex and opex cost.**	**Fully functional data center.**	**35% lower cost than site retrofit.**
▪ Turnkey center for 500-2,500 sq ft. ▪ Implement in 8-12 weeks.	▪ Standardized design for 5-20K sq feet. ▪ Save up to 50% operational costs.	▪ Rapidly deploy in 12-14 weeks. ▪ Ease of maintenance. ▪ Open architecture.	▪ In-row cooling for cooling on demand. ▪ No disruption to existing operations. ▪ Avoid over provisioning of cooling.

IBM

Real estate and facilities Energy Management across the infrastructure



IBM

We've only just begun to uncover what is possible when building a sustainable solutions…

- By helping to lower energy costs across-the-board for our clients; which also helps them overcome current operational barriers.
- Strengthening our clients' reputation while helping them meet environmental regulation requirements.
- Help create products and services that can give rise to new markets for our clients.

Let's work together to drive real progress in our time.

"The world is on the threshold of a new era of innovation and change with the rise of the **Industrial Internet**."

– Peter C. Evans,
GE Director of Global Strategy and Analytics

– Marco Annunziata,
GE Chief Economist

www.ge.com/sites/default/files/Industrial_Internet.pdf Nov 2012

Minds + Machines
November 29th, 2012

Powered by GE

The Industrial Internet Economy
Canadian Financial Post, May 2013

- The seeds of the Industrial Internet are already being planted in the Canadian economy.
- Sensor technologies are deployed in machinery to monitor equipment operations and manage the schedules and routes of transportation fleets.
- The Industrial Internet revolution begins with the choices of business visionaries.
- It will be managed and made valuable by the decision makers who rise to its opportunities.

http://business.financialpost.com/category/news/executive-summary/industrial-internet


Ted Talk by Marco Annunziata 12:37 mins
Chief Economist of General Electric Co.
http://www.ted.com/talks/marco_annunziata_welcome_to_the_age_of_the_industrial_internet


What caught your eye?