John Impagliazzo

# Ontem, Hoje e Amanhã: Computer Engineering and Other Curricula

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# **Computing Curricula**

**Ontem**Where we were

**Hoje**Where we are

Amanhã
Where we might be



## **Institutionally Sponsored Curricula**

### **Many Claims and "Firsts"**

First computing graduate

First computing doctorate

First computing program

First computing degree



## **Organizationally Sponsored** (1)

## **ACM Two-Year College "Mini" Reports**

Data Processing (ca. 1962)

#### **ACM Curriculum '68**

Mix of Math and Computing (1968)

### **Information Systems Report**

Independent, Dan Cougar (1973)

#### **ACM Curriculum '78**

Real Birth of Computer Science (1978)



## **Organizationally Sponsored (2)**

#### **ACM Curriculum Modifications**

Programming First (1983-1984) CS1, CS2, CS3, Discrete Structures

## **ACM Information Systems Report**

First Organizational IS report (1983)

## **IEEE Program in Computer Science and Engineering**

"Birth" of Computer Engineering as a Discipline (1984)

## **DPMA '90 Information Systems Curriculum**

Information Systems (1990)



## **Organizationally Sponsored (3)**

#### **ACM / IEEE Curriculum '91**

First Joint Organizational Report (1991)
Spurred by the Denning 1987 "Computing as a Discipline" Paper
Introduced Knowledge Areas and Knowledge Units
Abandoned Courses, Tried to be "One Size Fits All"
Arranged to Produce Thousands of Possible Curricula
Publishers Balked at the Recommendations – What Books to Publish?

## **ACM Reports on Associate-Degree Programs**

Four Reports: CS, IS, CET, CSS, Other Disciplines (1993) Very Popular, All Printed Copies Sold Out

#### ACM / AIS / DPMA/AITP IS Curriculum '97

A 'Tour de Force' Information Systems Curriculum (1997)
Known and Used Worldwide



## **Organizationally Sponsored (4)**

### **ACM / IEEE Computing Curriculum 2001**

CC '91 was Too Innovative had Basically Failed
Became the Update to CC '91
Really Became a Report on Computer Science
Recognized the Need for Other Non-CS Discipline Reports

#### ACM / AIS / DPMA/AITP IS Curriculum 2002

Update of IS'97 (1997)

### Other ACM Reports for Associate-Degree Programs

Curricula Updates (1995-2002)



# **Ontem: Computing Education Changed**

## Computing - a family of disciplines

- □ Pre-1990:
  - Computer Science on the technical side
  - Information Systems on the business side
- □ During the 1990s:
  - Computer Engineering became a strong discipline
  - Software Engineering sometimes thought as an area within CS and began its own identity
  - Information Technology programs was common worldwide but began emerging in the US in the 1990s



Pre-1990:

EE

CS

IS

**Hardware** 

**Software** 

**Business** 

Post-1990:

EE

CE

SE

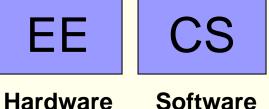
CS

IS

IT



## Pre-1990:

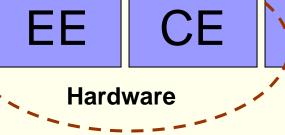


Software

IS

**Business** 

# Post-1990:



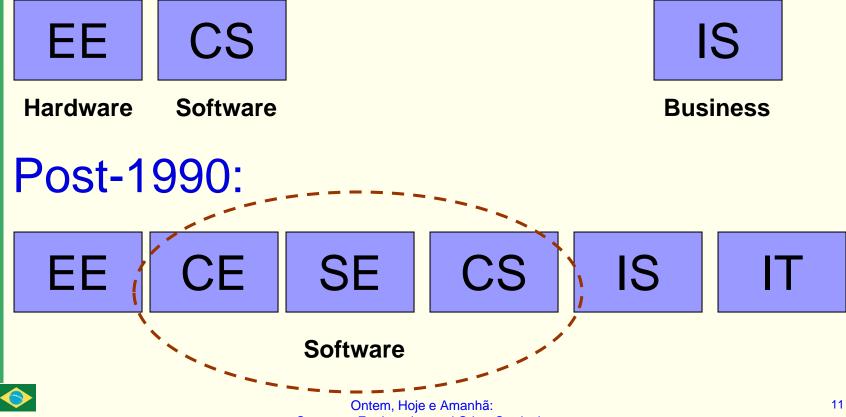
CS

IS



SE

## Pre-1990:



Pre-1990:

EE

CS

**Hardware** 

**Software** 

IS

**Business** 

Post-1990:

EE

CE

SE

CS

IS

ΙT

Organizational Needs



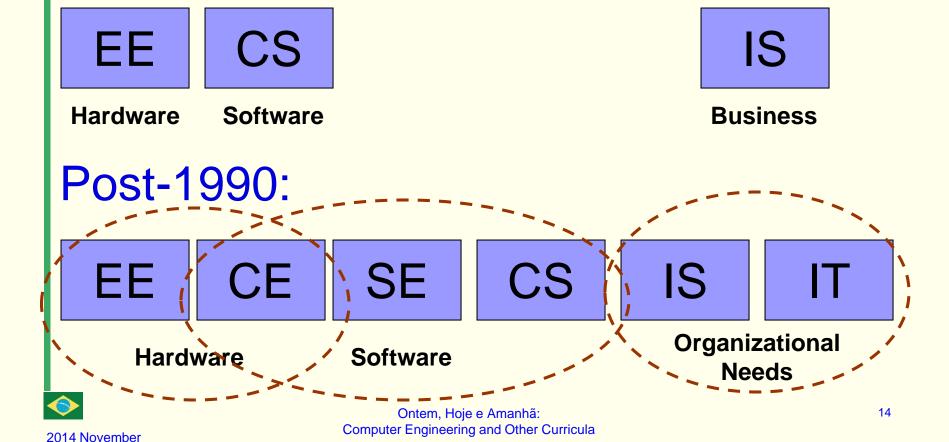
## **Ontem: Difference Between IT and IS**

## Both focus on using "Information Technology"

- Information Systems programs:
  - Focus on the *Information* side of *IT*
- Information Technology programs:
  - Focus on the Technology side of IT



## Pre-1990:



# **Computing Curricula**

2002

"Ontem" Ends

"Hoje" Begins



# **Hoje: Computing Curricula**

## **Organizationally Sponsored (1)**

## **ACM / IEEE Software Engineering Curriculum**

First of Curriculum Report in the Field (2004)

## **ACM / IEEE Computer Engineering Curriculum**

True CE-focused Report (2004)
Not Based on the 1984 IEEE Model

### **ACM / IEEE / AIS / Etc. Overview Report**

First of its Kind (2005)



# **Hoje: 2005 Overview Report**

## **Covers Five Undergraduate Degree Programs**

**Computer Engineering** 

**Computer Science** 

**Information Systems** 

**Information Technology** 

**Software Engineering** 



## Hoje: CC2005 Task Force

## Representatives of:

- ACM
- IEEE Computer Society
- Association for Information Systems
- ACM SIG Information Technology Education
- British Computer Society
- International Federation for Information Processing
- ABET and CSAB

## Participants from Curricula Task Forces:

- CS2001 (formerly known as CC2001)
- IS2002
- IT200X (later became IT2008)
- CE2004
- SE2004



# **Hoje: Six Curricular Reports**

□ Computer Science CS2001 (CC2001)

□ *Information Systems* IS2002

Software Engineering SE2004

□ **Computer Engineering** CE2004

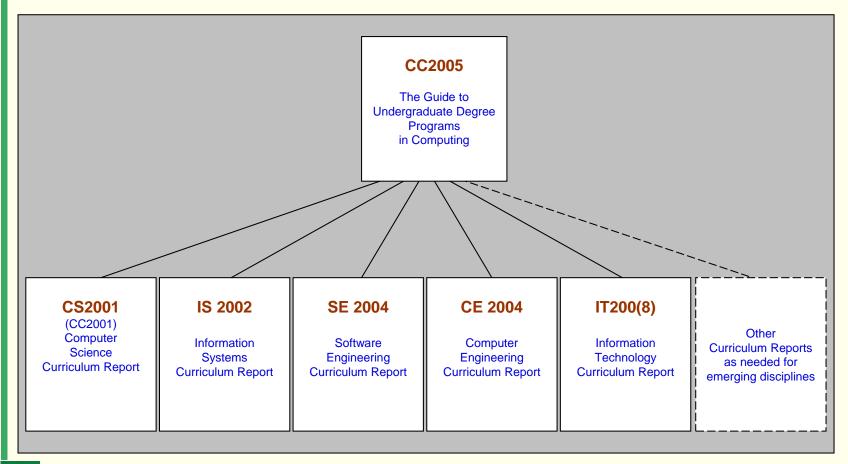
□ Information Technology IT200x

### □ *The Overview Report* CC2005

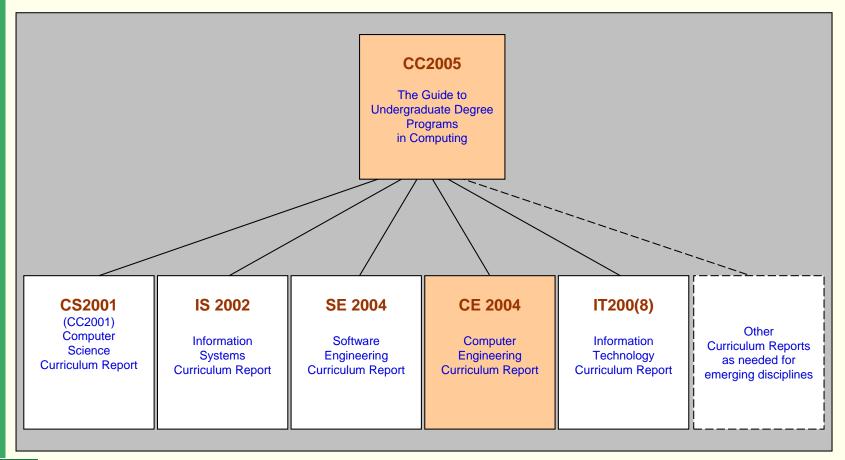
- Based on the Body of Knowledge from each of the above
- Report on commonalities and differences
- A users' guide to the computing disciplines
- A larger project to create a map of computing



# **Hoje: Organizational Structure**



## **Hoje: Organizational Structure**



# Hoje: Curricula Makeup (1)

- Computer Engineering
  - Design and construction of computers, and computer based systems (digital hardware/software systems)
  - Development of devices that have embedded systems
  - Integration of hardware and software
- Computer Science
  - Ranges from theoretical foundations to cutting-edge developments
  - Develop effective ways to solve computing problems
  - Designing and implementing software



# Hoje: Curricula Makeup (2)

#### □ Information Systems

- Satisfy informational needs of businesses and organizations and information provided by computer systems
- Determines requirements and design of an organization's information systems

### Information Technology

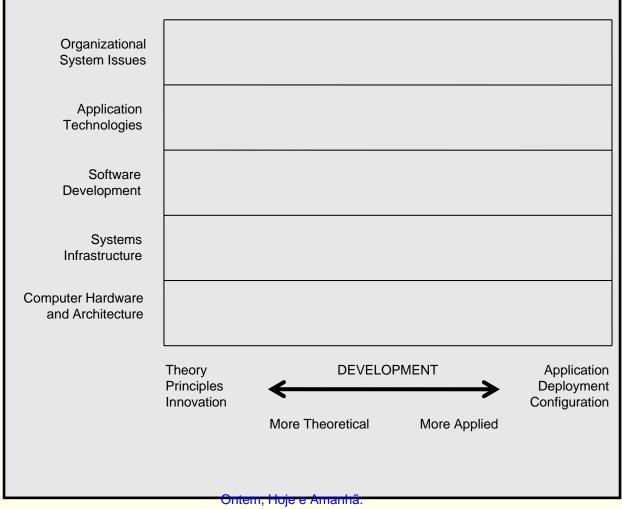
- Combination of knowledge and practical applications with hands-on expertise
- Maintain an organization's information technology structure and install computer systems

### Software Engineering

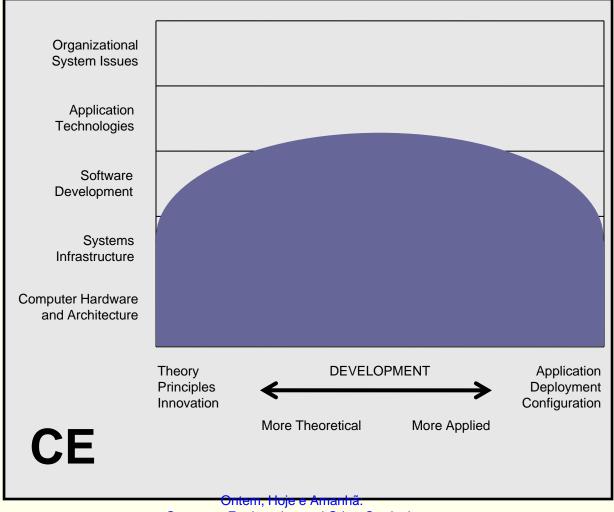
- Develop and maintaining large-scale, safety-critical, software systems
- Integrates the science of computer science with engineering principles and practices



# **Hoje: Computing Visualized**

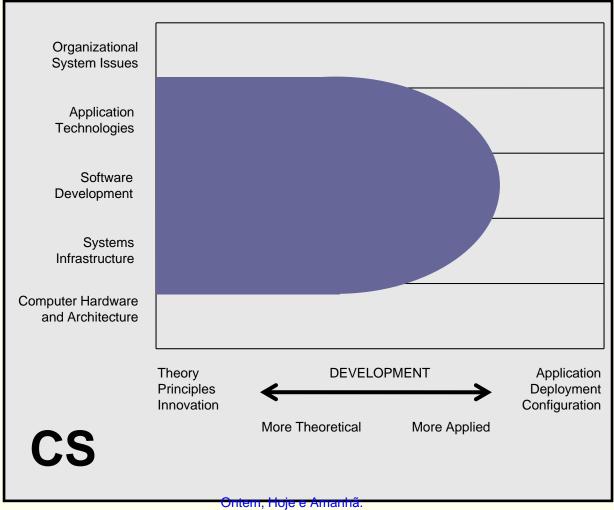


# **Hoje: Computer Engineering Visual**

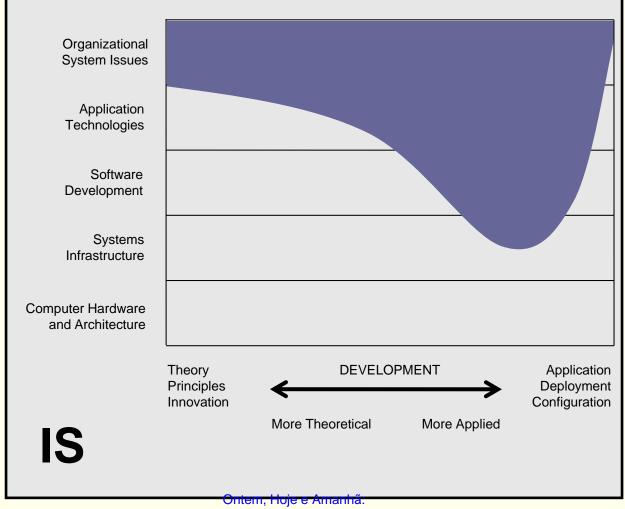




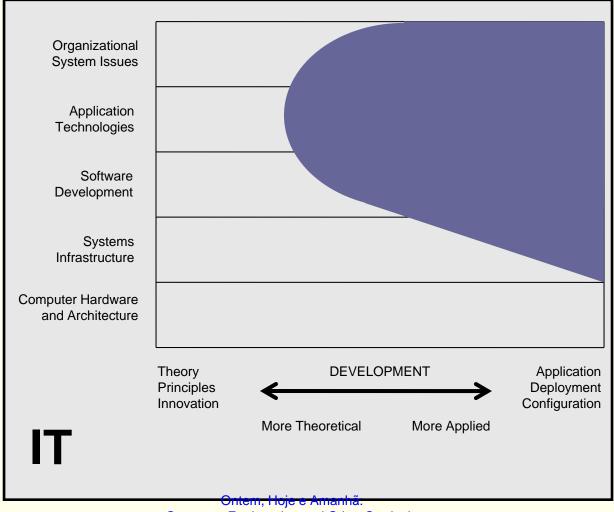
# **Hoje: Computer Science Visual**



# **Hoje: Information Systems Visual**

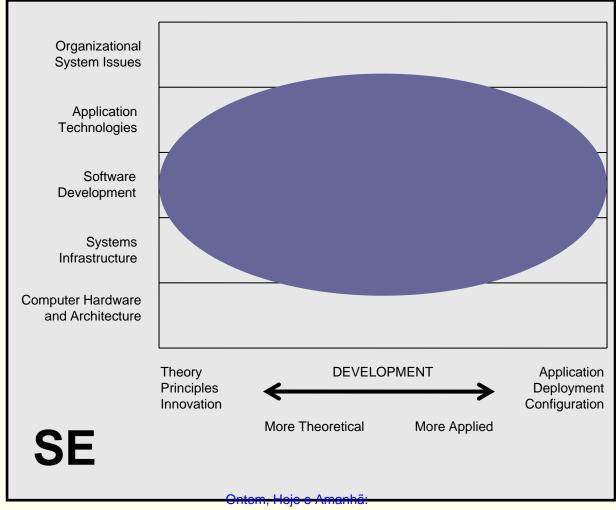


# **Hoje: Information Technology Visual**

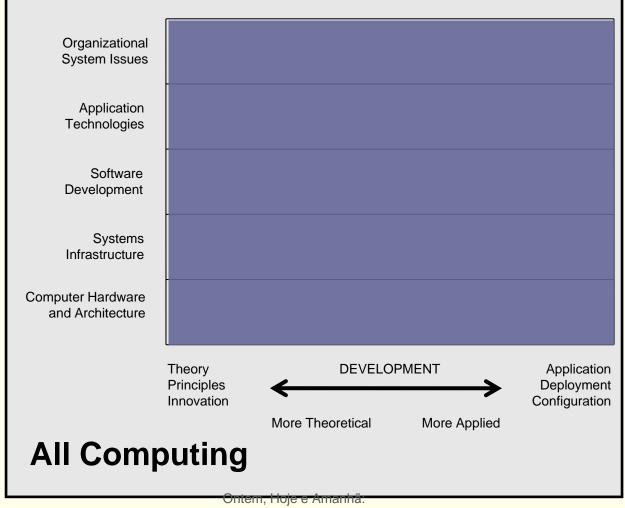




# **Hoje: Software Engineering Visual**



# **Hoje: Computing Visualized**





# **Hoje: Evolutionary Tendencies**

- One may view the aforementioned curricula as five segregated packages
  - Some commonalities and some differences
  - Not sensitive to needs of business and industry
- Universities teach, research, and provide services
  - Often done in isolation
  - Not integrated as a whole
  - Universities educate, they do not train
- Massive changes in business and industry
  - Universities often remain stagnant
  - Universities must evolve and adapt to societal needs
  - Students seek jobs with difficulty



## **Hoje: Computing Curricula**

## **Organizationally Sponsored (2)**

### **ACM / AIS Master's Information Systems Curriculum**

First of its Kind (2006)

### **ACM CS Curriculum Report**

Minor Update of CS2001 (2008)

### **ACM / IEEE Information Technology Report**

First of its Kind (2008)

## **ACM / AIS Information Systems Curriculum**

Update of Earlier Undergraduate Curriculum (2010)



# **Hoje: Outcome-Based Learning**

- The primary focus of outcome-based learning has led to <u>assessment</u>
- Activities:
  - Establish a mission and vision
  - Identify stakeholders
  - Create measurable (key) performance indicators
  - Establish student learning outcomes
  - Align outcomes with educational practice
  - Develop a documented assessment process
  - Collect data and information for the process
  - Assess the learning outcomes periodically
  - Evaluate the program
  - Modify elements (performance indicators, learning outcomes, course details, etc.) as needed to improve the program
  - Repeat the ongoing process



# **Hoje: Program Goals/Objectives**

### **Meaning**

 Statements that describe the expected accomplishments of graduates during the first few years after graduation

#### **Characteristics**

- Formulated by constituencies of the program (not necessarily the faculty)
- Must be long-term (at least three years) and measurable
- Must show significant achievements of graduates from the program

### Requirements

Graduates should achieve at least one (not necessarily all) objective

# **Hoje: Student Learning Outcomes**

#### **Meaning**

 Statements that describe what students are expected to know and be able to do by the time of graduation

#### **Characteristics**

- Formulated by the mission of the program
- Must be measurable
- Must document abilities of students upon graduation

### Requirements

Graduating students must achieve <u>all</u> program outcomes



# **Hoje: Assuring Quality**

#### **Question and Answer**

- Question: How do we know we are producing a quality product (student graduates) in response to current student attitudes, university changes, and global dynamics?
- Answer. Assessment

### **Two Definitions**

- Assessment: Processes that identify, collect, analyze, and report data that can be used to evaluate achievement
- Evaluation: Process of reviewing the results of data collection and analysis and making a determination of the value of findings and action(s) to be taken



# **Hoje: Types of Assessment**

#### Formative vs. Summative

- Formative == Periodic (continuous) assessment
- Summative == Determined at end of project or course

### Objective vs. Subjective

- Objective == Definitive responses to queries
- Subjective == Multiple (vague) responses to queries

#### Criteria-based vs. Norm-based

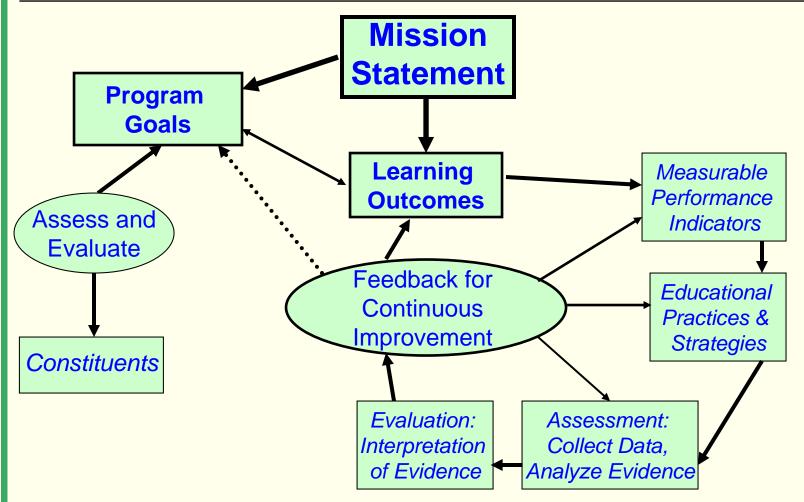
- Criteria-based == Conforms to specific standards
- Norm-based == focused on average or accepted beliefs

#### Formal vs. Informal

- Formal == Quantitative and qualitative facts
- Informal == Casual overall judgments



# **Hoje: Graphical View**





# **Hoje: Computing Curricula**

2012

"Hoje" Ends

"Amanhã" Begins



# Amanhã: Computing Curricula

### **Organizationally Sponsored (1)**

#### **ACM / IEEE Computer Science Curriculum**

Update of CS2001/CS2008 Reports (2013)
Used a Two-Tier Core of "Musts" and "Shoulds"
Many Exemplars of Existing Programs

### **ACM / IEEE Software Engineering Curriculum**

Update of SE2004 (2013-2014)
No Significant Improvement over SE2004

### **ACM Two-Year College Information Technology Curriculum**

Update from 2001 Document (2014) Very Avant Gard; Learning Outcomes Only



# Amanhã: Computing Curricula

### **Organizationally Sponsored (2)**

#### **ACM / IEEE Computer Engineering Curriculum**

Moderate Update of CE2004 Curriculum (2016)
Balanced Approach to Curriculum Reform

### **ACM Information Technology Curriculum**

Update of Earlier 2008 Undergraduate Curriculum (2017) Representatives from Four Countries with Great Diversity

### **ACM / AIS Information Systems Curriculum**

Update of Earlier 2010 Undergraduate Curriculum (201x)



# Amanhã: Computing Curricula

### **Organizationally Sponsored (2)**

### **ACM / IEEE Computer Engineering Curriculum**

Moderate Update of CE2004 Curriculum (2016)
Balanced Approach to Curriculum Reform



# Amanhã: CE2016 Team

### **ACM**

John Impagliazzo (Co-Chair)\*
Hofstra University

Susan Conry Clarkson University

Victor Nelson\*
Auburn University

Joseph Hughes\* Georgia Tech

Weidong Liu
Tsinghua University

Junlin Lu
Peking University

Andrew McGettrick\*
University of Strathclyde

### **IEEE Computer Society**

Eric Durant (Co-Chair)

Milwaukee School of Engineering

Herman Lam
University of Florida

Robert Reese
Mississippi State University

Lorraine M. Herger IBM Research

\* Member of CE2004 Team

### Amanhã: Team Activities

#### 2011 (Hoje)

- February: Goals / plan constituent involvement
- March: Revise survey
- April: Finalize survey, pilot group, launch
- □ June: Analyze & discuss results
- July: Report to IEEE-CS EAB and ACM Education Board

#### 2012

- March: SIGCSE Workshop
- Funding Issues
- October: FIE Special Session

#### 2013

- BoK area research, research on major new topics
- October: FIE pre-conference workshop

#### 2014

- April: Restructure BoK
- August: Review several KA drafts, settle on new format, draft core chapter
- October: FIE Workshop, Madrid
- December: IEEE TALE, New Zealand



# Amanhã: CE2016 Report Structure

#### **Contents**

Computer engineering as a discipline

**Principles** 

Body of knowledge

Engineering practice and the CE curriculum

**Professionalism** 

Curriculum issues

Institutional challenges

### **Appendices**

Body of knowledge Sample curricula



### Amanhã: Some CE Definitions

### **Academic Core Hour (c.h.)**

One academic "core" hour is the equivalent of a 50-minute lecture

#### **Learning Outcome (LO)**

Statements that describe what students are expected to know and be able to do by the time of graduation

#### **Knowledge Unit (KU)**

A kernel of information described by learning outcomes

### **Knowledge Area (KA)**

A collection of knowledge units that describe a unified area of importance

### **Body of Knowledge (BoK)**

A collection of knowledge areas containing a common theme



# Amanhã: CE2004 — BoK — KAS

**CE-ALG** Algorithms

CE-CSE Computer Systems
Engineering

**CE-DBS** Database Systems

CE-DSP Digital Signal Processing

**CE-ESY Embedded Systems** 

**CE-NWK Computer Networks** 

CE-PRF Programming Fundamentals

**CE-SWE** Software Engineering

CE-CAO Computer Arch. and Organization

CE-CSG Circuits and Signals

**CE-DIG** Digital Logic

**CE-ELE Electronics** 

CE-HCI Human-Computer Interaction

**CE-OPS Operating Systems** 

CE-SPR Social and Professional Issues

CE-VLS VLSI Design and Fabrication



# Amanhã: CE2016 — BoK — KAS

CE-CAE Circuits and Electronics

**CE-CAL** Computing Algorithms

CE-DIG Digital Design

**CE-NWK Computer Networks** 

**CE-SEC Information Security** 

**CE-SGP Signal Processing** 

CE-SWD Software Design

CE-CAO Computer Arch. and Organization

CE-CSE Computing Systems Engineering

**CE-ESY Embedded Systems** 

**CE-PFP** Professional Practice

CE-SET Strategies for Emerging Technologies

CE-SRM Systems Resource Management



# Amanhã: CE2016 & CE2004

#### **CE2016**

- Knowledge Areas:13
- Knowledge Units
- Learning Outcomes
- □ No topic
- □ Each KA has a Scope
- □ CE Core: 420 Hours
- Math Core: 110 Hours
- □ Vision: Futuristic

#### **CE2004**

- Knowledge Areas: 16
- Knowledge Units
- Learning Outcomes
- Topics
- □ No KA Scope
- □ CE Core: 420 Hours
- Math Core: 66 Hours
- □ Vision: State-of-Art

# Amanhã: Significant Revisions

- System on Chip (SoC) instead of VLSI
- Field Programmable Gate Array (FPGA) instead of Application Specific Integrated Circuit (ASIC)
- Multicore beyond parallel
- Security, particularly for networked and embedded devices, is now its own KA
- Mobile and other power-aware systems
- Software: object-oriented design, modern development processes (e.g., agile), refactoring
- Requirements, verification, validation for systems (encompasses hardware and software)
- Tools for hardware and software development and design
- Emerging technologies



## Amanhã: Credits and Time

#### **One Academic Hour**

One hour is the equivalent to the time for a 50-minute lecture

#### **One Academic Credit**

Equivalent to 15 academic hours including exams Consists of 14 academic hours excluding exams

#### **One Academic Year**

Equivalent to 30 academic credits == 450 academic hours Excluding exams, **one academic year == 420 academic hours** 

#### **Four-Year Academic Program**

Minimal four-year academic program is 120 credits == 1800 academic hours Excluding exams, four-year academic program == 1680 academic hours



# Amanhã: CE KAs, Math, and Core Hours

		Core Hours	Totals
CE-CAE	Circuits and Electronics	50	
CE-CAO	Computer Architecture and Organization	60	
CE-CAL	Computing Algorithms	30	
CE-CSE	Computing Systems Engineering	30	
CE-DIG	Digital Design	50	
CE-ESY	Embedded Systems	40	
CE-NWK	Computer Networks	20	
CE-PFP	Professional Practice	20	
CE-SEC	Information Security	20	
CE-SET	Strategies for Emerging Technologies	10	
CE-SGP	Signal Processing	30	
CE-SRM	Systems Resource Management	20	
CE-SWD	Software Design	40	420
CE-CAN	Analysis of Continuous Functions	30	
CE-DSC	Discrete Structures	30	
CE-LAL	Linear Algebra	20	
CE-PRS	Probability and Statistics	30	110
			530



# Amanhã: KA Example: ESY

#### **Area Scope**

#### The units in this knowledge area collectively encompass the following:

- Purpose and role of embedded systems in computer engineering, along with important tradeoffs in such areas as power, performance, and cost
- Embedded systems programing, either in assembly language or a high level language or both, for typical embedded systems applications using modern tools and approaches for development and debugging
- Digital interfacing using both parallel and asynchronous/synchronous serial techniques incorporating typical on-chip modules as such as general purpose I/O, timers, and serial communication modules (i.e., UART, SPI, I2C, CAN, etc.)
- Analog interfacing using analog-to-digital convertors connected to common sensor elements and digital-to-analog converters connected to typical actuator elements
- Mobile and wireless embedded systems using both short-range (Bluetooth, 802.15.4) and long-range (cellular, Ethernet) in various interconnection architectures

# Amanhã: ESY Knowledge Units

#### [40 Core Hours]

- CE-ESY-1 History and overview [1]
- CE-ESY-2 Relevant tools, standards, and/or engineering constraints [2]
- CE-ESY-3 Characteristics of embedded systems [2]
- CE-ESY-4 Basic software techniques for embedded applications [3]
- CE-ESY-5 Parallel input and output [3]
- CE-ESY-6 Asynchronous and synchronous serial communication [6]
- CE-ESY-7 Periodic interrupts, waveform generation, time measurement [3]

- CE-ESY-8 Data acquisition, control, sensors, actuators [4]
- CE-ESY-9 Implementation strategies for complex embedded systems [7]
- CE-ESY-10 Techniques for low-power operation [3]
- CE-ESY-11 Mobile and networked embedded systems [3]
- CE-ESY-12 Advanced I/O topics [3]
- CE-ESY-13 Computing platforms for embedded systems
- CE-ESY-14 Tradeoffs in embedded systems

# Amanhã: ESY Knowledge Units

#### [40 Core Hours]

- CE-ESY-1 History and overview [1]
- CE-ESY-2 Relevant tools, standards, and/or engineering constraints [2]
- CE-ESY-3 Characteristics of embedded systems [2]
- CE-ESY-4 Basic software techniques for embedded applications [3]
- CE-ESY-5 Parallel input and output [3]
- CE-ESY-6 Asynchronous and synchronous serial communication [6]
- CE-ESY-7 Periodic interrupts, waveform generation, time measurement [3]

- CE-ESY-8 Data acquisition, control, sensors, actuators [4]
- CE-ESY-9 Implementation strategies for complex embedded systems [7]
- CE-ESY-10 Techniques for low-power operation [3]
- CE-ESY-11 Mobile and networked embedded systems [3]
- CE-ESY-12 Advanced I/O topics [3]
- CE-ESY-13 Computing platforms for embedded systems
- CE-ESY-14 Tradeoffs in embedded systems

# Amanhã: KU Example: ESY-5

#### **ESY-5** Parallel input and output

Minimum core coverage time: 3 hours

#### Core Learning Outcomes:

- Describe the appropriateness of different I/O configurations (input, strong drive, weak pullup/pulldown, open-drain, tri-state) available in general purpose I/O (GPIO) for a given target application.
- Create programs that perform a sequence of input/output operations on one more GPIOs using a polled approach.
- Describe how interrupts are supported on the target embedded system(s).
- Create programs that perform a sequence of input/output operations on one more GPIOs using an interrupt-driven approach.
- Discuss mechanisms such as hardware and software FIFOs for buffering data streams.

#### Supplemental Learning Outcomes:

- Discuss Direct Memory Access (DMA) and describe how it is supported on the target embedded system.
- Create programs that perform a sequence of input/output operations using DMA.



### Amanhã: CE2016 Future Timeline

#### 2015\*

- Spring: Steering Committee meets and produces next major draft and releases for comments
- June: ASEE ECE Panel Discussion
- Other conference events planned (e.g., ECEDHA, FIE)

#### 2016\*

- June: ASEE
- Potential final version

\* Progression depends on feedback received

# Obrigado!

