Computer Science Curriculum 2013: Curricular Guidelines for the Next Decade

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Outline

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- The CS2013 Effort
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  - Charter and Themes
- CS2013 Strawman Report
  - Volume Contents
  - Characteristics of CS Graduates
  - The Body of Knowledge
  - Curricular Organization
- Community Engagement
  - Discussion

Computing Curriculum Background

- Every decade, ACM and IEEE-Computer Society jointly sponsor a curricular volume on Computer Science
  - Aimed at providing modern curricular guidance for undergraduate Computer Science programs internationally
  - Previous volumes in 1968, 1978, 1991, and 2001
  - Starting in 2001, volumes splits by disciplines:
    - Computer Science (CS), Computer Engineering (CE), Information Systems (IS), Information Technology (IT), and Software Engineering (SE)
  - Modest “interim” revision of CS volume was released in 2008
- Next full CS volume is set for release in 2013
  - Hence the name “CS2013”
  - Work on this volume began in Fall 2010

CS2013 Steering Committee

ACM

- Mehran Sahami, Chair (Stanford)
- Andrea Danyluk (Williams College)
- Sally Fincher (Univ. of Kent)
- Kathleen Fisher (Tufts University)
- Dan Grossman (Univ. of Washington)
- Beth Hawthorne (Union County Coll.)
- Randy Katz (UC Berkeley)
- Rich LeBlanc (Seattle Univ.)
- Dave Reed (Creighton)

IEEE-CS

- Steve Roach, Chair (U. of Texas, El Paso)
- Ernesto Cuadros-Vargas (Universidad Católica San Pablo, Peru)
- Ronald Dodge (US Military Academy)
- Robert France (Colorado State)
- Amruth Kumar (Ramapo College of NJ)
- Brian Robinson (ABB corporation)
- Remzi Seker (U. of Arkansas, Little Rock)
- Alfred Thompson (Microsoft)

CS2013 Charter

To review the Joint ACM and IEEE/CS Computer Science volume of Computing Curricula 2001 and the accompanying interim review CS 2008, and develop a revised and enhanced version for the year 2013 that will match the latest developments in the discipline and have lasting impact.

The CS2013 task force will seek input from a diverse audience with the goal of broadening participation in computer science. The report will seek to be international in scope and offer curricular and pedagogical guidance applicable to a wide range of institutions. The process of producing the final report will include multiple opportunities for public consultation and scrutiny.

High-Level Themes of CS2013 Effort

- "Big Tent" view of Computer Science
  - "Outward" looking view of the field
  - Making room for multi-disciplinary work ("Computational X")
- Managing curriculum size
  - Aim to not increase required hours from CC2001
  - Greater flexibility with respect to local needs/resources
- Course exemplars as opposed to stylized courses
  - Pointers to existing courses that incorporate knowledge units
  - Not creating a set of stylized reference classes
- Be aware of institutional needs
  - Variable goals, resources, and constraints
  - Variety of school sizes, school types, and available resources

Principles for CS2013

1. Identify **essential skills** and **body of knowledge** for CS undergraduates.
2. CS is rapidly changing field, drawing from and contributing to variety of disciplines. Prepare students for **lifelong learning**.
3. CS2013 is serving **many constituents**, including: faculty, students, administrators, curricula developers, and industry.
4. Curricular guidelines must be relevant to a **variety of institution types** (large/small, research/teaching, 4-yr/2-yr, US/int'l)
5. Provide **guidance for level of mastery for topics**, and show exemplars of fielded courses covering topics.
6. Provide **realistic, adoptable recommendations** that support novel curricular designs, and attract full range of talent to field.
7. Should include **professional practice** (e.g. communication skills, teamwork, ethics) as part of undergraduate experience.

CS2013 Contents: Strawman Report

- Guiding principles
- Body of knowledge
  - Topically organized set of “Knowledge Areas”
  - Knowledge Areas provide list of topics and learning outcomes
- Curricular structure
  - Guidance on how Body of Knowledge translates into curriculum
- Professional considerations
  - Characteristics of CS graduates

CS2013 Contents: Plan for Final Report

- Guiding principles
- Body of knowledge
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  - Knowledge Areas provide list of topics and learning outcomes
- Curricular structure
  - Guidance on how Body of Knowledge translates into curriculum
  - Institutional challenges
- Professional considerations
  - Characteristics of CS graduates
  - Professional practice
- Course and curricular exemplars
  - Pointers to and discussion of example curricula/courses reflecting diverse ways of covering the Body of Knowledge

Characteristics of CS Graduates

- Technical understanding of Computer Science
- Familiarity with common themes and principles
- Appreciation of the interplay between theory and practice
- System-level perspective
- Problem solving skills
- Project experience
- Commitment to life-long learning
- Commitment to professional responsibility
- Communication and organizational skills
- Awareness of the broad applicability of computing
- Appreciation of domain-specific knowledge

Professional Practice

- Computing professionals need training beyond technical skills, including:
  - Ethical reasoning and legal responsibility
  - Communication (written and oral)
  - Teamwork
  - Project management

- Chapter on Professional Practice will be forthcoming in future draft
  - Welcome thoughts to help develop this area

Updating the Body of Knowledge

- Strawman report: complete update of Body of Knowledge
  - Deemed most important in survey of department chairs
  - Drives discussion of pedagogy and complete curriculum
- Process for updating Body of Knowledge
  - Active subcommittee for each Knowledge Area
  - Chaired by a member of steering committee
    - Contains at least two other members of steering committee
    - Often contain additional (non-steering committee) members
  - Each area reviewed by several (often 4 or more) “external” reviewers prior to release of Strawman draft
  - Over 100 external reviewers involved

Knowledge Areas in CS2013

- AL - Algorithms and Complexity
- AR - Architecture and Organization
- CN - Computational Science
- DS - Discrete Structures
- GV - Graphics and Visual Computing
- HC - Human-Computer Interaction
- IAS - Information Assurance and Security
- IM - Information Management
- IS - Intelligent Systems
- NC - Networking and Communications
- OS - Operating Systems
- PBD - Platform-based Development
- PD - Parallel and Distributed Computing
- PL - Programming Languages
- SDF - Software Development Fundamentals
- SE - Software Engineering
- SF - System Fundamentals
- SP - Social and Professional Issues

Body of Knowledge Update (Part 1)

- Two "foundational" KAs
  - Software Development Fundamentals
    - Includes content from old Programming Fundamentals, Software Engineering, and Algorithms and Complexity areas
    - Identifies foundational (paradigm-independent) concepts and skills (paradigms moved to Programming Languages)
    - Seeks to broaden thinking away from equating “Programming Fundamentals” with introductory programming courses (CS1,2)
  - Systems Fundamentals
    - Includes content from old Operating Systems, Architecture and Organization, and Algorithms and Complexity areas
    - Cross-cutting systems concepts (e.g., caching, locality, latency)
    - Avoids tying these to any one topic (e.g. Operating Systems, Architecture) to foster broader thinking and new pedagogy

Body of Knowledge Update (Part 2)

- Other new Knowledge Areas
  - Information Assurance and Security
    - Most important area to add based on survey of dept. chairs
    - Includes additional core curricular hours
  - Parallel and Distributed Computing
    - Second most important area to add based on survey of chairs
    - Includes additional core curricular hours
  - Networking and Communications (replaces Net-Centric Computing)
    - Sharpens focus on networking
    - Web development moves to “Platform-based Development”
  - Platform-based Development (elective only)
    - E.g., web, mobile devices, game consoles, robots, etc.

Curricular Organization (Part 1)

- Three-tiered classification of Body of Knowledge Units
  - **Core-Tier1**: absolutely essential topics, all of which are required for any undergraduate CS program
  - **Core-Tier2**: important foundational topics, the vast majority (no less than 80%) of which should be in a CS program
    - Still considered “Core” topics – ideally all Tier2 topics would be included in an undergraduate program, if possible
    - Tiering allows for flexibility to locally customize curricula
  - **Elective**: additional topics that can be included to complete an undergraduate CS program
    - Covering just “core” material is insufficient for a complete curriculum

Curricular Organization (Part 2)

- Guidance provided on depth of coverage for learning outcomes in each Knowledge Area
  - 3 levels of depth: *Knowledge*, *Application*, and *Evaluation*
  - Knowledge: know what it means
  - Application: can apply concept (e.g., write the code to use it)
  - Evaluation: can compare/contrast/select appropriate method/strategy for different situations

- Knowledge Areas are ***not*** necessarily courses
  - For example, introductory programming course might include:

    Software Development Fundamentals (key concepts) +

    Programming Languages (paradigm/language) +

    Platform (e.g., mobile devices or robots)

Example of Knowledge Area

Parallel and Distributed Computing (PD)

The past decade has brought explosive growth in multiprocessor computing, including multi-core processors and distributed data centers. As a result, parallel and distributed computing has moved from a largely elective topic to become more of a core component…

PD. Parallel and Distributed Computing (5 Core-Tier1 hours, 9 Core-Tier2 hours)

	Core-Tier1 hours	Core-Tier2 hours	Includes Electives
PD/Parallelism Fundamentals	2		N
PD/Parallel Decomposition	1	3	N
PD/Communication and Coordination	1	3	Y
PD/Parallel Algorithms, Analysis, and Programming		3	Y
PD/Parallel Architecture	1	1	Y
PD/Parallel Performance			Y
PD/Distributed Systems			Y
PD/Formal Models and Semantics			Y

Example of Knowledge Unit (Topics)

PD/Communication and Coordination

[1 Core-Tier1 hour, 3 Core-Tier2 hours]

Topics:

[Core-Tier1]

- Shared Memory
- Sequential consistency, and its role in programming language guarantees for data-race-free programs

[Core-Tier2]

- Consistency in shared memory models
- Message passing
- Point-to-point versus multicast (or event-based) messages
- Blocking versus non-blocking styles for sending and receiving messages
- Message buffering (cross-reference PF/Fundamental Data Structures/Queues)
- Atomicity

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[Elective]

- Consensus
- (Cyclic) barriers, counters, or related constructs

…

Example KU Learning Outcomes

1. Use mutual exclusion to avoid a given race condition [Application]
2. Give an example of an ordering of accesses among concurrent activities that is not sequentially consistent [Knowledge]
3. Explain when and why multicast or event-based messaging can be preferable to alternatives [Knowledge]
4. Write a program that correctly terminates when all of a set of concurrent tasks have completed [Application]
5. Use a properly synchronized queue to buffer data passed among activities [Application]

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Bounding Size of Curriculum

Knowledge Area	CS2013 Tier1	CS2013 Tier2
AL-Algorithms and Complexity	19	9
AR-Architecture and Organization	0	16
CN-Computational Science	1	0
DS-Discrete Structures	37	4
GV-Graphics and Visual Computing	2	1
HC-Human-Computer Interaction	4	4
IAS-Security and Information Assurance	2	6
IM-Information Management	1	9
IS-Intelligent Systems	0	10
NC-Networking and Communication	3	7
OS-Operating Systems	4	11
PBD-Platform-based Development	0	0
PD-Parallel and Distributed Computing	5	10
PL-Programming Languages	8	20
SDF-Software Development Fundamentals	42	0
SE-Software Engineering	6	21
SF-Systems Fundamentals	18	9
SP-Social and Professional Issues	11	5
Total Core Hours	**163**	**142**

All Tier1 + All Tier2 Total	**305**
All Tier1 + 90% of Tier2 Total	**290.8**
All Tier1 + 80% of Tier2 Total	**276.6**

Bounding Size of Curriculum

Knowledge Area	CS2013 Tier1	CS2013 Tier2	CS2008 Core	CC2001 Core	2007 LACS
AL-Algorithms and Complexity	19	9	31	31	69
AR-Architecture and Organization	0	16	36	36	40
CN-Computational Science	1	0	0	0	0
DS-Discrete Structures	37	4	43	43	49
GV-Graphics and Visual Computing	2	1	3	3	0
HC-Human-Computer Interaction	4	4	8	8	5
IAS-Security and Information Assurance	2	6	0	0	0
IM-Information Management	1	9	11	10	0
IS-Intelligent Systems	0	10	10	10	4
NC-Networking and Communication	3	7	15	15	10
OS-Operating Systems	4	11	18	18	9
PBD-Platform-based Development	0	0	0	0	0
PD-Parallel and Distributed Computing	5	10	0	0	0
PL-Programming Languages	8	20	21	21	47
SDF-Software Development Fundamentals	42	0	47	38	39
SE-Software Engineering	6	21	31	31	20
SF-Systems Fundamentals	18	9	0	0	0
SP-Social and Professional Issues	11	5	16	16	11
Total Core Hours	**163**	**142**	**290**	**280**	**303**

All Tier1 + All Tier2 Total	**305**
All Tier1 + 90% of Tier2 Total	**290.8**
All Tier1 + 80% of Tier2 Total	**276.6**

Engaging the Community

- Website: **`cs2013.org`**
  - Dissemination of report drafts (Strawman report available)
  - Community engagement
    - Use Ensemble for commenting/feedback
- Multiple opportunities for involvement in this effort
  - Comments on Strawman draft
  - Mapping exemplar courses/curricula to Body of Knowledge
  - Pedagogic approaches and instructional designs
    - Address professional practice within undergraduate curricula
  - Share institutional challenges (and solutions to them)
  - Suggest roles that can contribute to this effort

Timeline

- Feb. 2012: Strawman draft (alpha) public release
  - Includes: Body of Knowledge, Characteristics of Graduates
- July 2012: Comment period for Strawman closes
  - Next steering committee meeting to discuss feedback starts August 2nd
- Feb. 2013: Ironman draft (beta) public release
  - Incorporates feedback on Strawman draft
  - Includes: Body of Knowledge, Characteristics of Graduates, Curricula and Course Exemplars, Professional Practice, Institutional Challenges
- June 2013: Comment period for Ironman draft closes
- Summer 2013: Final report released (general availability)

Feedback on CS2013

- Comments on the Strawman report?
  - Positive and negative reactions
  - Issues of Characteristic of CS Graduate/Professional Practice
    - Especially the role of project experiences
  - Thoughts on the Body of Knowledge

- What might help with adopting new curricular recommendations in CS2013?
  - What are institutional challenges (and potential solutions)?

- Additional comments?