Upper Level Course Requirements

Proposal by Mike Hicks

Problem

There is significant demand for 42X courses (i.e., those in the information processing area). The major requirements aimed at ensuring breadth limit students’ ability to take these courses. But doing so seems unnecessarily strict, as these courses exhibit significant breadth, with offerings in graphics, machine learning, computational biology, and databases.

This proposal aims to address this problem by still requiring “5 courses in 3 areas” but removing the limit of 2 courses in a single area. We discuss this proposal below, along with two alternative proposals that we think are inferior.

Background

In all, 42X is the largest area in terms of courses offered, and we are increasing our capacity to offer seats in this area, with many TTk faculty hires being made in AI, ML, VR, etc. Conversely, we are standing still in other areas, and as such tend not to staff courses as much in those areas. For example, 436 and 430 are typically offered only once per year. At the extreme, the numerical analysis (46X) area consists of only two courses, and only one of them is eligible for the degree requirements.

Here is a tally of the enrollment in 400-level, area-requirement courses since Fall’15:

<table>
<thead>
<tr>
<th></th>
<th>Fall’15</th>
<th>Spring’16</th>
<th>Fall’16</th>
<th>Spring’17</th>
<th>Fall’17</th>
<th>Spring’18</th>
<th>Fall’18</th>
<th>Courses</th>
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<tbody>
<tr>
<td>409</td>
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<td>409</td>
<td>403</td>
<td>479</td>
<td>496</td>
<td>428</td>
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<td>740</td>
<td>772</td>
<td>1021</td>
<td>863</td>
<td>42X</td>
<td></td>
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<td>316</td>
<td>380</td>
<td>325</td>
<td>453</td>
<td>321</td>
<td>371</td>
<td>547</td>
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<td></td>
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<td>105</td>
<td>176</td>
<td>165</td>
<td>181</td>
<td>172</td>
<td>249</td>
<td>260</td>
<td>45X</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>39</td>
<td>46X</td>
<td></td>
</tr>
<tr>
<td><strong>1330</strong></td>
<td><strong>1345</strong></td>
<td><strong>1419</strong></td>
<td><strong>1796</strong></td>
<td><strong>1744</strong></td>
<td><strong>2137</strong></td>
<td><strong>2137</strong></td>
<td><strong>TOTAL</strong></td>
<td></td>
</tr>
</tbody>
</table>

Offering/demand for 42X courses has significantly outpaced 41X+43X, more than doubling between Spring’16 and Spring’18. During that same period, 41X+43X together increased by only 28%. Whereas in Spring’16 this pair offered more seats that 42X, in Spring’18 it offered fewer. During the same period, 45X+46X exhibited a milder upward trend, with far fewer seats offered that the other two groupings overall. This may be a consequence of the fact that the current scheme does not require everyone to take an upper-level theory course.

In sum: The current breadth requirements have not changed even as upper-level class offerings have evolved significantly. This makes them less effective at actually enforcing breadth, and
they create an impediment to students attempting to graduate on time due to mismatched availability of seats.

**Status Quo**

The following was copied from the [undergraduate degree web page](#), describing the current requirements.

At the upper level, students take five (5) CMSC 400 level courses from at least three different areas with no more than two courses in a given area. An additional two (2) CMSC electives, totaling 6 credits, for the general computer science degree are also required. Students may take up to three 1 credit CS courses to fulfill their elective credits requirement. If students take more than two courses from an area, the additional courses will be counted as upper level computer science electives. Students can also count one credit winter courses towards the elective requirement, as well as independent research or study with a faculty member, and other courses at the 300 or 400 level, including special topics courses.

**Area 1: Systems**
- CMSC 411 (3) Computer Systems Architecture
- CMSC 412 (4) Operating Systems
- CMSC 414 (3) Computer and Network Security
- CMSC 417 (3) Computer Networks

**Area 2: Information Processing**
- CMSC 420 (3) Data Structures
- CMSC 421 (3) Introduction to Artificial Intelligence
- CMSC 422 (3) Machine Learning
- CMSC 423 (3) Bioinformatic Algorithms, Databases, and Tools
- CMSC 424 (3) Database Design
- CMSC 426 (3) Image Processing
- CMSC 427 (3) Computer Graphics

**Area 3: Software Engineering and Programming Languages**
- CMSC 430 (3) Introduction to Compilers
- CMSC 433 (3) Programming Language Technologies and Paradigms
- CMSC 434 (3) Introduction to Human-Computer Interaction
- CMSC 435 (3) Software Engineering
- CMSC 436 (3) Hand Held Programming Devices

**Area 4: Theory**
- CMSC 451 (3) Design and Analysis of Computer Algorithms
- CMSC 452 (3) Elementary Theory of Computation
- CMSC 456 (3) Cryptology
- CMSC 457 (3) Quantum Computation
Area 5: Numerical Analysis (choose one)
CMSC 460 (3) Computational Methods (credit will only be given for CMSC 460 or CMSC 466)
CMSC 466 (3) Introduction to Numerical Analysis (credit will only be given for CMSC 466 or CMSC 460)

Proposed Change
The favored proposal is simply the following:

At the upper level, students take five (5) CMSC 400 level courses from at least three different areas with no more than two courses in a given area. [Rest same as before]

Analysis
This change permits students to take three courses from an area (i.e., 3-1-1), rather than two (i.e., 2-2-1), while ensuring that three areas are covered. As such, students would be able to sign up for more 42X courses and take advantage of the breadth and capacity offered there. Of course, they could also sign up for more 43X and 41X courses than the current scheme. There is some breadth in these areas too, that might be more fairly covered, e.g., 434 is quite different from 433, and 414 is quite different from 411 or 412. But, as these areas have lower capacity, the added flexibility will make it easier for students to get the courses they need to graduate, while also satisfying demand.

All course patterns currently allowed would be allowed under the proposed scheme. This makes the transition process for PCC quite easy.

Alternative Proposed Change #1
One alternative proposal is to split 42X courses into two sub-areas, thus permitting taking advantage of their inherent breadth. The changes to the current policy are simple, and highlighted below.

At the upper level, students take five (5) CMSC 400 level courses from at least three different areas with no more than two courses in a given area. An additional two (2) CMSC electives, totaling 6 credits, for the general computer science degree are also required. Students may take up to three 1 credit CS courses to fulfill the their elective credits requirement. If students take more than two courses from an area, the additional courses will be counted as upper level computer science electives. Students can also count one credit winter courses towards the elective requirement, as well as independent research or study with a faculty member, and other courses at the 300 or 400 level, including special topics courses.

Area 1: Systems
CMSC 411 (3) Computer Systems Architecture
As above, all course patterns currently allowed would be allowed under the proposed scheme. Newly allowed course patterns permit taking greater advantage of the breadth of the offerings in the 42X area. As a consequence, they essentially permit dropping a course that might otherwise have been required from 41X, 43X, 45X, 46X in aggregate. For example, the new scheme would permit the five courses 411, 412 (Systems), 421, 422 (IP-A), and 423 (IP-B), whereas one of the 42X classes would need to be replaced with a 43X, 45X, or 46X course in the current scheme. Relaxing the limit to two courses in an area (per the favored proposal, above) would still not
allow this schedule as one of the 41X courses would have to be replaced if all 42X courses were retained.

On the other hand, the above schedule shows that three of the current areas could be avoided under this proposal, which may be viewed as a negative. One potential mitigating factor is that there is some overlap between 41X and 43X courses, so some concepts would still be covered if one area was dropped. E.g., 412 covers topics of concurrency, software engineering, handler-oriented programming, and performance tuning, meaning that it overlaps with higher-level concepts that would have been covered in 433 or 436.

**Alternative Proposed Change #2**

An alternative proposal discussed last summer was the following: (1) collapse the Systems and SE/PL/HCI into a single area, (2) collapse Theory and Numerical Analysis into a single area, and (3) change the "5 courses in 3 areas" requirement to be "at least one course in each area." Highlighted differences below.

At the upper level, students take five (5) CMSC 400 level courses, with at least one from each area. An additional two (2) CMSC upper-level electives, totaling 6 credits, for the general computer science degree are also required. Students may take up to three 1 credit CS courses to fulfill the their elective credits requirement. If students take more than three courses from an area, the additional courses will be counted as upper level computer science electives. Students can count up to three one credit winter courses towards the elective requirement as noted above, as well as independent research or study with a faculty member, and other courses at the 300 or 400 level, including special topics courses.

**Area 1: Software and Systems**
- CMSC 411 (3) Computer Systems Architecture
- CMSC 412 (4) Operating Systems
- CMSC 414 (3) Computer and Network Security
- CMSC 417 (3) Computer Networks
- CMSC 430 (3) Introduction to Compilers
- CMSC 433 (3) Programming Language Technologies and Paradigms
- CMSC 434 (3) Introduction to Human-Computer Interaction
- CMSC 435 (3) Software Engineering
- CMSC 436 (3) Hand Held Programming Devices

**Area 2: Information Processing**
- CMSC 420 (3) Data Structures
- CMSC 421 (3) Introduction to Artificial Intelligence
- CMSC 422 (3) Machine Learning
- CMSC 423 (3) Bioinformatic Algorithms, Databases, and Tools
- CMSC 424 (3) Database Design
- CMSC 426 (3) Image Processing
CMSC 427 (3) Computer Graphics
CMSC 470 (3) Natural Language Processing [TBA]

Area 4: Theory and Numerical Analysis
CMSC 451 (3) Design and Analysis of Computer Algorithms
CMSC 452 (3) Elementary Theory of Computation
CMSC 454 (3) Algorithms for Data Science [TBA]
CMSC 456 (3) Cryptology
CMSC 457 (3) Quantum Computation
CMSC 460 (3) Computational Methods (credit will only be given for CMSC 460 or CMSC 466)
CMSC 466 (3) Introduction to Numerical Analysis (credit will only be given for CMSC 466 or CMSC 460)

Analysis

Very few CS students take a numerical analysis class (e.g., 115 students are taking 460 in Fall’18, and only 30 of them are CS students, out of 2400 seats total at the 400 level), so combining it with theory has little practical impact on students’ choices.

This rearrangement should force a bit more breadth than the current scheme. For one, it would prevent a student from avoiding all 400-level theory courses, e.g., by taking 411, 412 (systems), 433, 434 (PL/SE/HCI), and 422 (IP). This would be disallowed in the proposed scheme, as 411, 412, 433, and 434 are part of one area (software and systems). In addition, the proposed scheme permits greater breadth within the information processing area, since three courses there would be allowed. This is useful and sensible because that information processing is so broad, including courses on AI, Computational Biology, Databases, and Computer Graphics. A student could take, for example, 421, 422, 424, 430, and 456.

On the other hand, it limits prior flexibility in areas that were previously separate. This is the flip side of the first example above (e.g., taking two 43X classes and two 41X classes would no longer be allowed except by treating 1-2 of them as electives). Arguably, the overlap among the combined areas reduces the harm from lack of breadth. For example, 412 covers topics of concurrency, software engineering, handler-oriented programming, and performance tuning, meaning that it overlaps with higher-level concepts that would have been covered in 433 or 436. That said, this scheme still has the potentially perplexing including of HCI classes within the “software and systems” area, but this is no worse than the current scheme.

The major disruption of this scheme is that all students will be required to take at least one 400-level theory course. Just looking at the numbers we saw above, it seems likely that some fraction of students today are not taking a theory course.

<table>
<thead>
<tr>
<th>Courses</th>
<th>Fall'15</th>
<th>Spr'16</th>
<th>Fall'16</th>
<th>Spr'17</th>
<th>Fall'17</th>
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<td>165</td>
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</tr>
</tbody>
</table>
Requiring a theory course could significantly impact both teaching habits, and may create a significant challenge for many of our students. Our graduation rate is already among the lower rates on campus, and we may not want to inflate that.