ICCAD’14 CEDA Luncheon Keynote:

Teaching EDA at Planetary Scale:
Reflections on the First EDA MOOCs

Rob A. Rutenbar
Abel Bliss Professor & Head
Massive Open Online Courses

Internet-scale video (for instruction) + Cloud-based assignments (for eval & grading) = MOOCs
A Very Big Idea (Not Without Controversy...)

MOOC Brigade: Will Massive, Open Online Courses Revolutionize Higher Education?

On the plus side, MOOCs are free, open to anyone and taught by professors at prestigious universities. On the downside, they have low completion rates, and critics question the utility of students being graded by their peers. TIME is enrolling in several of these classes to see what all the fuss is about.

By KAYLA WEBLEY (September 4, 2012)

http://nation.time.com/2012/09/04/mooc-brigade-will-massive-open-online-courses-revolutionize-higher-education/

The New York Times

The Opinion Pages

Revolution Hits the Universities

By THOMAS L. FRIEDMAN

Published: January 27, 2013

This CEDA Keynote: My MOOCs

- From March – May 2013, I did the first **EDA MOOC** delivered on the Coursera platform ([www.coursera.org](http://www.coursera.org))

- From March – May 2014, I did the **AGAIN** (2\textsuperscript{nd} offer).

- From Feb – April 2015, I will do it **YET AGAIN** (3\textsuperscript{rd} offer)
About This Talk

First EDA MOOCs

- What?
- How?
- Why?
A Little Context: Why The Name?

- I spent 25 years on faculty at Carnegie Mellon
- And I taught this class...
  - For 20 years, about 15 times, to ~750 students
  - Class called: VLSI CAD: Logic to Layout

To recruit fresh talent, cannot use an unfamiliar name. Course is “CAD”
What Does my “Regular” Class Teach?

ASIC Flow
- Logic + Layout
- Synthesis + Verification
- Logical/Electrical Timing

Not here (no time): behavioral, simulation, test, ...
Physical On-Campus Class ➔ MOOC

- My physical class is
  - 15 weeks
  - 948 PPT slides
  - 20 separate slide decks
  - Delivered as ~14x3 hours
    = 52 hours of lecs

- But MOOC need not be same length & intensity as a standard semester
Designing Coverage for my MOOC

- Walking thru each lec slide by slide, and chunking into individual essential topics, was for me a very useful exercise
  - I have ~102 separate topics, with per-topic slides counts below
Closeup on Topical Coverage

- Example of 2 topics, up close, PPT lecture slide counts

### Computational Boolean Algebra
- cofactors
- bol diff
- quantif defns
- network repair
- compu strategies URP

### BDDs
- BDD basic defs ROBDD
- Building, Var order, Simple SAT
- Multi root, GC
- Neg arc
- Ops, Retrict & ITE
- ITE implementation, hash tables
Result: From Regular Course to MOOC

Regular class:
- 20 Lectures
- 948 PPT slides

69 Short Video Lectures
- Average length: 15 minutes
- 615 total PPT slides
- 17 total lecture hours / 10 weeks

à 50-60% of regular course, in about 1/3 of the time
MOOC Video Content: Minutes/Lecture, by Week

1. Comp Bool Alg
2. BDDs & SAT
3. Logic Synth I
4. Logic Synth II
5. Placement
6. Tech Map
7. Routing
8. Timing
Tool Tutorials

Why so short?
1. Focus
2. Bandwidth
What’s In A Video Lecture?

Start: Title about content

Next: “Talking head” intro
What’s In A Video Lecture?

- Example “talking Rob head” intro of lecture topic
What’s In A Video Lecture?

- Deep content is me **writing** on the slides of lecture + **voiceover**

![Multiple-Cube Extraction: # Literals Saved](slide16.png)

**Before**

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- $\sum$ element values = 20
- $\sum$ row weights = 10
- $\sum$ column weights = 2

(value sum) – (row sum) – (column sum) = \(20 - 10 - 2 = 8\)

- $P = af + bf + ag + cg + ade + bde + cde$
- $Q = af + bf + ace + bce$
- $R = ade + cde$

**After**

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- $P = Xde + Xf + ag + cg + cde$
- $Q = Xce + Xf$
- $R = ade + cde$

Change in # literals = 33 – 25 = 8!
What About MOOC Assignments?

- **8 weekly Homewoeks, 1 Final Exam**
  - Multiple choice
  - True/False
  - Number-in-a-box, etc

- **NOTE:** our MOOC is **semi-synchronous**
  - Watch videos *whenever*, but all assignments have **deadlines**

- **What’s different than in-class versions?**
  - **Math:** Can’t do derivations
  - **Randomize:** Must “over supply” problems (cheating)
  - **Partitioning:** A *big* problem → *Small*, step-by-step parts
MOOC Assignments

- Lots of criticism of MOOCs being “dumbed down”
  - Yes, a bit simpler. No, not a lot “dumber”
  - Mostly, burden on instructor to **design smart assignments**
  - Ex: this is the “macro answer” to one factoring HW problem

NEW: **Randomize**

1. Over-supply all problems
2. “Bind” to learners at login access
3. Combats cheating
MOOC Assignments: 2 Paths Thru Class

Grading: Certificate & 2 Badge Options

Two options for a *Statement of Accomplishment* Certificate

- **Achievement Badge**
  - 8 Problem Sets = **75%**
  - Single submission; late submission allowed after deadline for 50% of credit
  - 1 Final exam = **25%**
  - Single submission.

- **Mastery Badge**
  - 8 Problem Sets = **40%**
    - Same single submit policy
  - 4 Program Assignments = **40%**
    - Multiple submissions ok; late submission allowed after deadline for 50% of credit
  - 1 Final exam = **20%**
    - Same single submission

**Idea:** Do this if you don’t have time to do all the code

**Idea:** Do this for *deepest* understanding of course
EDA MOOC: Software

- Fact: Cannot teach a serious EDA course without...
  - Experimenting with some existing EDA tools
  - Designing software for some new EDA tools

- How to do this at scale? To >10,000 students?
  - Vendors: Not giving us free stuff
  - Openness: Problems with IP, Legal, Licensing, etc

- Answers
  - Open source software
  - From-scratch software
VLSI CAD MOOC: Software Ecosystem

Tool Portals for Student Use

- kbdd
- miniSAT
- espresso
- SIS
- Ax=b

Input: Text file
Output: Webpage

Project Auto-Graders

- Prog1
- Prog2
- Prog3
- Prog4

Input: Text file
Output: Webpage
VLSI CAD MOOC: Software Ecosystem

kbdd

Tool output → Private webpage

kbdd.txt

Coursera

Amazon Web Services

Slide 21
VLSI CAD MOOC: 4 Software Projects

1. Boolean Data Structures & Computation (URP, PCN)

2. BDD-based Logic Network Repair

3. Quadratic Placement

4. ASIC Maze Routing
Logistics for MOOC EDA Software Projects

- **ASCII text in → text out**
  - Avoids platform, language, and security issues with code
  - Upload file, we autograde it

- **Architected just like industrial regression suite**
  - Many benchmarks
  - Big and small
  - Partial credit & feedback

- **Ex: Router project**


Slide 23
Software Project Examples: Layout

Recursive Quadratic Placer

2-Layer ASIC Router
New Problem: How Can Students See Layout?

- Can’t control what platform they use!
- Answer: custom HTML5 geometry web-based environment
  - If they have a modern browser, they can drag/drop text file

(HTML5 design and pic by Nicholas Chen)
The Elephant In The (MOOC) Room...

LOTS of people start...

NOT so many people finish.
1st VLSI CAD MOOC: Participant Landscape

- 17,500 registered learners at peak
- 7,000 people watched a video
- 1,300 people did a homework
- 400 people tried a software assignment
- 500 people took the Final Exam
- 386 *Statement of Accomplishment* Cert’s

**DEMOGRAPHICS**

- Average age: 30  Min: 15  Max: 75
- Have a Bachelors: 30%  Have MS/PhD: 29%
- Male: 88%  Female 12%
University of Illinois Coursera Students: VLSI CAD Percent of Students by Country

VLSI CAD Student Percent
- 0%
- 0.01 - 1%
- 1.01 - 2.5%
- 2.51 - 5%
- 5.01 - 10%
- 10.01 - 29.69%

ATLAS Statistics Group
University of Illinois
Data gathered between Fall 2012 and Spring 2013
Bigger than CDNS; a bit smaller than SNPS

Roughly attendance at DAC’13

Roughly equivalent to 40 years of students for this course

Many ways to deliver educational value in a MOOC; it’s not all about how many people take the Final...
Things One Learns in MOOC-Land

My handwriting **unreadable**
for a planetary audience

Creativity to make homeworks
in multiple-choice format

MOOCers crave **interaction**
with instructors, 24x7!

Be sensitive to **diversity** of
IT resources of participants

** = when 2 or more individual variables in the main loop "For (each variable x in F) yield the same solution for F/x, we just draw them pointing to the same child box in our diagram of the progress of the algorithm.**
My MOOCers: Want More EDA...

Word-cloud from Final Exam question: what else would you like us to cover
Why...?

A decade ago, lots of EDA classes, lots of students...

Today: Not so much, any more...
Why Did I Do This...?

Because every vibrant discipline needs a solid on-ramp, to teach people the basics, how we solve things...
Reflections...

- If we want to energize a new generation of EDA...
  - Moving EDA into other areas or kinds of systems
  - Moving EDA into new technology platforms (eg, post-Moore)
  - Translating EDA “sideways” into adjacent opportunity areas

- ...somebody must teach foundations
  - Maybe planet only supports a handful of global EDA courses
  - If so, OK – here’s how you do it...
What is *Demand* for Planet-Scale EDA MOOC?

- To answer this: I ran it *again* March - May 2014
- Registrations for 2014 VLSI CAD: Logic to Layout
What is *Demand* for Planet-Scale EDA MOOC?

10K+ registered in MOOC #2 = *Big enough*...
Aside: MOOC(#1) + MOOC(#2)

- Over 27,000 learners registered for my MOOCs (so far)

**My MOOCs slightly larger than estimated worldwide population of EDA pro’s**

Source: Patrick Groeneveld, Synopsys Inc., from “Correct by Construction or Construct by Correction; Tales from the Edge of Science and Business,” Valedictory Symposium for Prof. Dr. Ir. R.H.J.M. Otten, Eindhoven, May 23rd, 2014.
Summary

- I taught 1st (and 2nd) EDA MOOCs, will do 3rd shortly
  - Why? Because *somebody* has teach this to the planet.
  - Why? Because *these ideas are beautiful and important.*
  - Why? Because *need* excitement for vibrancy of discipline.

- Depending on your count, I added *500-2500 seriously EDA-trained humans* to planet Earth over last ~2 years

- I think this is a pretty good start...