Software for instructors preparing algorithm visualization examples

Härmel Nestra
Institute of Computer Science
University of Tartu
e-mail: harmel.nestra@ut.ee

Introduction
Problem

Most CS students in University of Tartu hardly understand general descriptions of algorithms.

Data about the bachelor level A&DS course


  Starting from 2009, we introduced algorithm visualization (with chalk on blackboard) for all students of the course.

- The exam results improved steeply.

- In both cases, students were allowed to use written materials, e.g. textbooks, workbooks etc..
Comparison of 2008 and 2009

The exam results (including resits) in numbers of obtained marks:

<table>
<thead>
<tr>
<th>Mark</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>D</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>E</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td>F</td>
<td>54</td>
<td>15</td>
</tr>
</tbody>
</table>

Other changes

Not all of this improvement was due to the algorithm visualization.

- Exam form changed (theory questions replaced by “pragmatics” questions).
- Computer labs introduced, report paper abandoned.
Remembering the material

This improvement is visible also in the results of tests done at the beginning of the master level Algorithmics course (using materials was not allowed).

<table>
<thead>
<tr>
<th>BST exercise performance (%)</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>39</td>
<td>31</td>
<td>22</td>
<td>53</td>
<td>46</td>
</tr>
</tbody>
</table>

2 Automatization
The new level

For the A&DS course in 2013, I prepared slide shows for many algorithms, in order to save time at blackboard (and chalks and my lungs).

- Slide shows demonstrate the behaviour of algorithms step-by-step.
- Steps are chosen to be intuitively comprehensible, resembling those performed on blackboard.
- Some brief explanations in words also included at each step.

Comparison with visualizations elsewhere

There are many algorithm visualization tools that can be freely downloaded from the Internet.

- Steps typically associated to some concrete implementation code, upstaging the “big picture”.
- Sometimes driven from some aesthetic form of output not helping to understand the idea of the algorithm.
- Often designed primarily for testing purposes.
Slide show generation

I wrote a tool in OCaml for automatic generation of algorithm visualization slide shows.

– Intended for course instructors.

State of the art

• Nearly 2.5 MB of source code.

• Covers almost all algorithms taught in the course except for graph algorithms.

• Generates three files: MetaPost source, LaTeX source and a shell program that compiles them and generates the pdf outcome.

• An intermediate representation of pictures enables replacing the LaTeX and MetaPost backends if desired.

• No user interface so far.
Usage

- For preparing a new example on an implemented algorithm, just make a copy of a frontend file and change the parameters (a user interface would make it trivial).

- For enabling examples of a new algorithm, one must define breakpoints in the algorithm implementation and specify what and how to show in the slides for every breakpoint (creative programming needed).

- For enabling new data structures, one must define how to depict the data structures (more creative programming needed).

History

I started to develop this software in 2008 and continued last autumn after many years.

- Intended initially for collecting algorithm implementation examples that could be relatively easily understood by students and perfectly executable at the same time.

- Turned out to be too complicated for that purpose, whence I re-targetted it to slide show generation.
Similar tools?

Students spend much time in the Internet, also because of searching good learning materials, and often find useful things before the instructors.

I asked them to notify me when they find any other tools of algorithm visualization designed for similar purposes.

- No notifications so far.
**Difference of teaching methodology in 2012 and 2013**

In my practical classes, I now showed the slides instead of showing the steps of algorithms on blackboard.

- Slides can be easily taken back if necessary.
- I always continuously explained what is going on (not relying on the brief summaries on the slides only).

**Comparison**

- During the practicals in 2013, I experienced that the students learned the algorithms faster and with less misunderstandings than before (concluded by feeling, with no measurement).

- However, the results of the exam were somewhat worse than before:

<table>
<thead>
<tr>
<th>Mark</th>
<th>2012</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>B</td>
<td>19</td>
<td>19</td>
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<tr>
<td>C</td>
<td>19</td>
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<td>36</td>
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<tr>
<td>F</td>
<td>54</td>
<td>52</td>
</tr>
</tbody>
</table>
### Possible reasons

- In 2013, students attended classes considerably less than usually.
  - I don’t know whether the results of active students became better.
- Students taking the course in 2013 were the first to enter the university according to new curriculum. Unfortunately, the workload turned out to be unbalanced throughout the semesters.
  - They had only one hard course in the second semester (Algebra) but 3–4 hard courses in the third semester (including A&DS).
- The content of the course also became bigger than it had been meanwhile (2010–2012).

### An undesired trend

Many students did not understand the purpose of the slides right.

- Thought that they were samples of right answers of the test paper and exam.
- Imitated the slide shows in the test paper, not reading the exercises carefully to understand what was actually required.
A theoretical reason

Especially mathematicians believe that teaching with chalk at blackboard is more efficient than using slides.

– This is due to showing also the process (e.g. of proving theorems) to students, not only the results.

– This should not make difference in my case since my slides actually show the process!

Conclusion
Instead of conclusion

• I plan to continue using the slide shows in the following years.

• If I get students who are interested in this, I may supervise further developments of the slide show generation tool:
  – Including graph algorithms and class tree algorithms.
  – Creating a user interface.