Interactive Learning Environments for Mathematical Topics

Doctoral examination

Ruedi Arnold
Interactive Learning Environments for Mathematical Topics

InfoTraffic is a collection of learning environments

LogicTraffic  QueueTraffic  DynaTraffic
Motivation: Logic in General Education

Problem

- Comprehension of logic is fundamental
- Today little significance in school practice

Analysis: Commonly taught in abstract manner and reduced to mathematical set of formulas

\[
\text{Modus Ponens: } \left( (p \rightarrow q) \land p \right) \models q
\]

Solution: We offer a new approach to propositional logic based on real-world experience
Propositional logic: truth table, Boolean operators, equivalence of formulas...
Queueing theory: throughput, utilization, Poisson distribution, arrival process, …
DynaTraffic
Analysis and Prediction of Traffic Distribution

Everyday situation

Simple model with cars

Abstract model without cars

Transition matrix

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.16</td>
<td>0.33</td>
<td>0.00</td>
<td>0.42</td>
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<tr>
<td>B</td>
<td>0.47</td>
<td>0.67</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>C</td>
<td>0.38</td>
<td>0.00</td>
<td>0.71</td>
<td>0.00</td>
</tr>
<tr>
<td>D</td>
<td>0.00</td>
<td>0.00</td>
<td>0.29</td>
<td>0.58</td>
</tr>
</tbody>
</table>
DynaTraffic
Analysis and Prediction of Traffic Distribution

Step 1: model of an everyday situation

Step 2: transformation of the model

Step 3: define assumptions
Markov Chains and Dynamic Systems: steady-state, transition matrix, periodic states, stochastic matrix, …
ICT as a Tool
- For everyday tasks (office, Internet, entertainment, …)
- For specific tasks (accounting, math, publishing, …)

ICT as a Medium
- Support teaching and learning
- Two main modes
  - Communication with other humans
  - Topic-specific educational software

ICT as a Subject
- Important concepts of computer science like programming, algorithms, propositional logic, queuing theory, or networks
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InfoTraffic: Interactive Learning Environments (ILEs) for important concepts from computer science and math
Didactical Concepts behind InfoTraffic
1. Content based on Fundamental Ideas

Propositional logic, queuing theory, and Markov chains are fundamental ideas according to Schwill [1]
- Different applications
- On different cognitive levels
- Historically and in the longer perspective relevant
- Connection to everyday language and actions

⇒ It’s important and therefore worth the effort!

Didactical Concepts behind InfoTraffic

2. High Level of Interactivity

Schulmeister [1]: 6 levels of interactivity

- 6: Intelligent feedback
- 5: Construction of own objects
- 4: Modification of parameters
- 3: Different representations
- 2: Navigation
- 1: Display only

Attractive for the „Nintendo Generation“ according to Guzdial and Soloway [2] (animation, different possibilities for interaction)

Didactical Concepts behind InfoTraffic

3. Different Representations

Offering different representations: thinking can happen in three different media according to Bruner et. al [1]. Supplemented by a fourth representation by Hartmann et. al [2]

Symbolic - symbol

„tree“

Iconic - picture

Enactive - action

Virtual-enactive - simulated action

Teaching often based on the rule-e.g.-rule technique, according to Bligh [1]

1. For abstract content better use e.g.-rule-e.g.-rule:

   e.g. rule e.g. rule

   Introduce Queues as M/M/1 system or as ?

2. References to prior knowledge based on an example from everyday life

Multiple visualizations of the same content, automatically updated allows different approaches to the content, depending e.g. on the students’ cognitive preferences and capabilities.
## Summary of Didactical Concepts behind InfoTraffic

<table>
<thead>
<tr>
<th>Didactical Concept</th>
<th>LogicTraffic</th>
<th>QueueTraffic</th>
<th>DynaTraffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental Idea covered</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Level of Interactivity</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Different Representations</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Begin with example from everyday life</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Corresponding Views</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Evaluation of InfoTraffic
Interdisciplinary Research

Educational science: fundamental research

Computer science: applied research

Research in computer science education, e.g., development of interactive learning environments

Teaching reality: use in practice
Evaluation of ILEs from the Perspective of Educational Science

Classical scientific evaluation of effectiveness of learning environments is not appropriate [1,2]:

- “Complexity of real learning and teaching situations sets tight limits to experimental research. This leads to the case that most comparisons of teaching methods and teaching media show no significant results, and the few significant results contradict each other.” [1]
- “Difficulties in generalizing statements from evaluations regularly tempt methodologists into calling for further differentiation and control in the methodical design. This leads to the construction of utterly artificial learning environments, whose evidence thus loses its validity for real life situations.” [2]
- “…we do not need any of those ‘careful studies of the impact of ... on ...’.” [2]

The Approach of InfoTraffic

Current trend in educational sciences: focus more on design, development, and use [1,2,3]

Engineering Science Approach

- Pragmatically combine the best findings available
- Directly concerned with practical impact. “Understanding how the world works and helping it ‘to work better’ by designing and systematically developing high-quality solutions to practical problems.” [2]

Impact of InfoTraffic on School Practice

Freely available online along with teaching material on a popular educational server

Used many times in high schools and teacher education courses

swisseduc.ch
Informatik » LogicTraffic: Aussagenlogik zur Sicherheit bei Strassenkreuzungen

Unterrichtsmaterial zu LogicTraffic
Verfasst von Ruedi Arnold

<table>
<thead>
<tr>
<th>Fachgebiet</th>
<th>Bool'sche Aussagenlogik</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schultyp</td>
<td>Gymnasien, Berufsschulen, Technikschulen, Fachhochschulen, Universitäten, etc.</td>
</tr>
</tbody>
</table>

Voraussetzungen: keine

Dauer: 2-4 Lektionen

Worum geht es?

Downloads zu "Unterrichtsmaterial zu LogicTraffic"

- Einführungsvortrag "Kleiner Ausflug in Logik und Verkehrsteuerung" PDF [209 KB] Powerpoint [809 KB]
- Handzettel 'Aufgabe Wahrheitstabelle' zum Einführungsvortrag PDF [89 KB] Powerpoint [73 KB]
- Anleitung zu LogicTraffic PDF [57 KB] Word [109 KB]
- Aufgaben zu LogicTraffic PDF [64 KB] Word [10 KB]
- Lösungen zu den Aufgaben zu LogicTraffic PDF [81 KB] Word
Impact of InfoTraffic
Anecdotal Evidence

“Logik ist cool!” (Spontaneous statement of a high school student after having attended an introductory presentation to LogicTraffic)

“Poissonverteilung ist viel zufälliger, nicht wie bei einem Fliessband, wenn jede Sekunde ein Teil aus der Maschine kommt.” (High school student after having solved exercises with QueueTraffic)


“I really believe that interactive learning with devices such as LogicTraffic is the best way for today’s generation of students to learn.” (American university professor using LogicTraffic in his classes)
Pragmatic Recommendations for Development of ILEs [1]

Contributions of this thesis

A real-world-based approach to propositional logic, queuing theory, and Markov chains

Guidelines for pragmatic and interdisciplinary engineering of ILEs

A virtual-enactive introduction to topics from math and computer science

“Logik ist cool!” Increasing the significance of logic in general education
The End - Thank you

Relevant publications


Acknowledgements

http://www.swisseduc.ch/compscience/infotraffic

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