ACM SIGCSE 2007

Technical Symposium on Computer Science Education

InfoTraffic –
Teaching Important Concepts of Computer Science and Math through Real-World Examples

Ruedi Arnold, ETH Zurich
Marc Langheinrich, ETH Zurich
Werner Hartmann, PH Bern
InfoTraffic is a collection of learning environments for teaching important concepts of computer science and math.

- Motivation: Abstract concepts are easier to introduce with the help of real-world examples

LogicTraffic  QueueTraffic  (DynaTraffic)
LogicTraffic & QueueTraffic

**LogicTraffic: propositional logic**
- Truth tables, operators, normal forms, equivalence...
  ➔ Make intersections safe!

**QueueTraffic: queuing theory**
- Arrival rate, throughput...
  ➔ Simulation & analysis of traffic jams!

⇒ Freely available online along with teaching material
⇒ Used and tested many times in Swiss high schools and teacher education courses
LogicTraffic: Propositional Logic at Intersections

Requirement: **no collisions!**

- What must hold that no collisions are possible?
- How can this be specified with propositional logic?

Solution here e.g.: \( \neg A \lor \neg B \)
LogicTraffic: GUI

Traffic situation

Truth table

Formula to the truth table

Formula editor
LogicTraffic: Short Demo

\[(\neg A \land \neg B) \lor (\neg C)\]
QueueTraffic: Queuing Theory at Intersections

Simulation and analysis of queues at traffic intersections
- Variation of parameters
- Observation of outcome

Introduction to concepts of queue theory
- Arrival rate
- Throughput
- Utilization and congestion
- Poisson vs. uniform distribution
- ...

![QueueTraffic Simulation](image)
QueueTraffic: GUI

Traffic situation

Data / charts

Traffic control

Traffic intensity

Simulation control
# QueueTraffic: Data and Charts

<table>
<thead>
<tr>
<th>Data</th>
<th>Charts</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival Rate (per Round)</td>
<td></td>
<td>28</td>
<td>25</td>
<td>13</td>
<td>26</td>
<td>91</td>
</tr>
<tr>
<td>Effective Throughput (per Round)</td>
<td></td>
<td>27</td>
<td>26</td>
<td>15</td>
<td>27</td>
<td>95</td>
</tr>
<tr>
<td>Traffic Intensity</td>
<td></td>
<td>1.00</td>
<td>0.89</td>
<td>0.46</td>
<td>0.93</td>
<td>0.81</td>
</tr>
<tr>
<td>Nr. of Cars</td>
<td></td>
<td>16</td>
<td>25</td>
<td>11</td>
<td>61</td>
<td>113</td>
</tr>
<tr>
<td>Waiting Cars</td>
<td></td>
<td>14</td>
<td>25</td>
<td>0</td>
<td>45</td>
<td>84</td>
</tr>
<tr>
<td>Avg. Nr. of Cars</td>
<td></td>
<td>16.67</td>
<td>22.99</td>
<td>10.60</td>
<td>40.57</td>
<td>90.83</td>
</tr>
<tr>
<td>Avg. Time in System</td>
<td></td>
<td>12.64</td>
<td>14.70</td>
<td>29.19</td>
<td>14.82</td>
<td>17.84</td>
</tr>
</tbody>
</table>

![Graph showing data and charts](image)
QueueTraffic: Sample Calculations

- **Arrival rate:**
  \[ \lambda = \frac{10 \text{ cars}}{60 \text{ s}} \]

- **Effective throughput:**
  \[ \mu_e = \frac{9 \text{ cars}}{60 \text{ s}} \]

- **Theoretical throughput:**
  \[ \mu_t = \frac{28 \text{ s}}{60 \text{ s}} \times \frac{1 \text{ car}}{1 \text{ s}} = \frac{28 \text{ cars}}{60 \text{ s}} \]

- **Utilization:**
  \[ \rho = \frac{\lambda}{\mu_t} = \frac{10 \text{ cars}}{60 \text{ s}} \div \frac{28 \text{ cars}}{60 \text{ s}} = 0.36 \]

---

- Calculated
- Simulated
  - (counted)
Main Didactical Concepts

1. Choice of content
   - Design of learning environment
   - Use in class
1. Content: Fundamental Ideas

- Propositional logic and queuing theory are fundamental ideas according to [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!

2. Design: Interactivity

- Schulmeister [4]: 6 levels of interactivity
  1. Display only
  2. Navigation
  3. Different representations
  4. Modification of parameters
  5. Construction of own objects
  6. Intelligent feedback

- Attractive for the „Nintendo Generation“ according to [5] (Animation, different possibilities for interaction)

2. Design: Different Representations

Three basic representations according to [2], supplemented by a virtual one by [3]

- Thinking: formal operation possible in different media

Symbolic - symbol

„tree“

Iconic - picture

Enactive - action

Virtual-enactive - simulated action

2. Representations in LogicTraffic

• Symbolic

\[(\neg A \land \neg B) \lor (\neg C)\]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

• Iconic

• Virtual-enactive
3. Use: eg-rule-eg-rule or Advance Organizer +

- Teaching often based on the rule-eg-rule technique [6]
  
  \[
  \text{rule} \quad \text{e.g.} \quad \text{rule}
  \]

- For abstract content better use eg-rule-eg-rule:
  
  \[
  \text{e.g.} \quad \text{rule} \quad \text{e.g.} \quad \text{rule}
  \]

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

- Different view: Extension of an advance organizer [7]
  
  - Not only begin with a summary and references to prior knowledge, but with an elaborate example known from everyday life.

Underway: DynaTraffic
   - Dynamic Systems, Markov chains

Remarks?
Questions?

Contact: Ruedi Arnold, rarnold@inf.ethz.ch
Project page: http://people.inf.ethz.ch/rarnold/infotraffic/
SW & teaching material: http://swisseduc.ch/compscience/infotraffic/
http://swisseduc.ch/compscience/infotraffic/