An effective quality measure for prediction of context information

Yves Vanrompay
Stephan Mehlhase
Yolande Berbers

Department of Computer Science
Katholieke Universiteit Leuven
Belgium

European Media Laboratory (EML)
Heidelberg, Germany

CoMoREA2010
Outline

- Introduction
- MUSIC project
- Learning operators
- Certainty measure for prediction
- Conclusions and perspectives
Introduction

- Pervasive systems
  - Adapt to changing environments
  - Ensure QoS and optimize resource usage
  - Proactive behavior
- Context-awareness involves:
  - Proactively adapt to changing environments and take decisions
  - E.g. memory shortage
- Learning of patterns and prediction of context information
- Example:
  - Predicting expected time of network connection availability of technician who follows typical working day path through building
MUSIC Project

- IST-MUSIC
  - www.ist-music.eu

- MUSIC: Self-adapting applications for Mobile Users In ubiquitous Computing environments

- Focus on the development of context-aware and self-adapting applications
  - Software systems capable of being adapted to highly dynamic user and execution context
MUSIC Project

- Variability support at design and runtime
  - Several implementations with the same functional capabilities
  - Different non-functional context-related properties
- Model-driven development
- Methodology, middleware and tools

01 April 2010
Learning operators

- Learning and prediction operators
  - As plug-ins of the context middleware
- Operators are instantiated as context plug-ins by specifying metadata
  - Context type that will be learned (and thus provided)
  - Required context types (possibly from context storage)
  - QoS metadata: resources consumed
  - Parameters of learning operator (or default)
Learning operators

Algorithm

Listener

Predictor Plugin

4. register listener

3. activate

7. learn

8. update prediction

MUSIC Context Middleware

5. values

6. values

Location Plugin

extends

Ants Context Plugin

1. register

9. values

2. activate

extends
Certainty measure

- Certainty $c$ of prediction
  - Assess the probability of a prediction being correct
  - Measure of how confident we can be in the predicted result
  - Suppose: $m$ predicted results, operator returns most probable one
    - $p$ equals $1/m$ iff all predicted values have same probability
    - Otherwise $p > 1/m$

\[ c = \frac{p - \frac{1}{m}}{1 - \frac{1}{m}} \]
Certainty measure

• Suppose you can place 2 bets on the outcome of an experiment
  – 2 equal probabilities of 0.5:
    • Divide bets, uncertainty maximal
  – 1 probability of 0.6, others equal 0.05:
    • Put all bets on 0.6, less uncertainty
Certainty measure

- Dataset of MavHome project
  - Time series of rooms a person is in (85000 entries)
- Algorithms:
  - 1<sup>st</sup> and 5<sup>th</sup> order Markov chains
  - Active Lempel-Ziv algorithm (with constant memory consumption)
  - HMM (with online learning)
- Weighted error rate:

\[ e = \frac{1}{n} \sum_{t=1}^{n} w_t \pi_t \quad \text{with} \quad \pi_t = \begin{cases} 1 & \text{Prediction wrong at time } t \\ 0 & \text{else} \end{cases} \]
Certainty measure

- Weights:
  - Certainty value of prediction
  - Penalize prediction errors that are made with high certainty
  - Unweighted error rate: $w = 1$
  - Threshold: 0.8

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Unweighted Rate</th>
<th>Weighted Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without</td>
<td>with threshold</td>
</tr>
<tr>
<td>Active Lempel-Ziv</td>
<td>0.2196</td>
<td>0.0881</td>
</tr>
<tr>
<td>1st-order Markov chain</td>
<td>0.2442</td>
<td>0.1275</td>
</tr>
<tr>
<td>5th-order Markov chain</td>
<td>0.2218</td>
<td>0.0884</td>
</tr>
<tr>
<td>HMM</td>
<td>0.2711</td>
<td>0.0874</td>
</tr>
</tbody>
</table>
Certainty measure

![Graph showing the relationship between certainty and probability](image)

**Fig. 2.** Probability of a correct prediction given the certainty for the HMM (dark-grey squares), the Active Lempel-Ziv (light-grey circles) and the 1st order Markov Chain (black triangles).
Conclusions

• Prediction operators integrated in MUSIC context middleware
• Quality of predicted context: certainty measure

• Future work:
  – Evaluate on different datasets
  – Combine with uncertainty of input values
An efficient quality measure for prediction of context information

Thanks !!
Questions?