Game Mastering in Collaborative Multiplayer Serious Games

3rd Research Talk @ KOM
Agenda

Introduction
- Motivation and Goal
- Roadmap

Concept and Architecture
- Research Questions
- Architecture
- Game Mastering Interface

Adaptation Engine
- Rule-based Adaptation
- Model-based Adaptation

Evaluation
- Game Master Frontend
- Game Mastering Effectiveness
- Adaptation Effectiveness

Summary and Outlook
Motivation

Computer-Supported Collaborative Learning (CSCL)

Today
- Well-established in curricula and training
- Mainly E-Learning tools

Challenges
- Instructor role is **vital**
- Instructors often **Digital Immigrants**

Serious Games

Today
- Promising examples / High potential
- Alternative and Supplement

Challenges
- Mainly **Singleplayer**
- No instructor inclusion

Image source: CROKODIL [BCR11]

Image source: www.enercities.eu
Motivation: Role of the Instructor in CSCL

Instructor/Teacher/Trainer Tasks

Analysis
Monitoring

Moderation
Guidance
Coaching
Intervention

Learning Progress
Learning Behavior
Communication
Teamwork
Interaction Process

Goal

Development of methods and concepts for Instructor Support in Collaborative Multiplayer Serious Games

Serious Games Technology
- Fun
- Immersion
- Interactivity

CSCL Technology
- Group work
- Collaboration
- Moderation
- Coaching

Instructor Support

Image sources: www.enercities.eu; CROKODIL [BCR11]
Research Environment

**A Collaborative Multiplayer Serious Game with Game Master Support**
contains features of Serious gaming, CSCL and methods for Game Mastering

Design of collaborative Multiplayer Serious Games

Development of methods and concepts For Game Mastering / Instructor Support

(related work: see [Aylett2007], [Baker1997], [Dillenbourg1999], [Effelsberg2005], [Haake2004], [Prensky2003], [Tychsen2005], [Tychsen2008], [Wechselberger2008], [Zagal2006], [Zea2009])

## Roadmap

<table>
<thead>
<tr>
<th>State of the Art</th>
<th>Adaptation &amp; User Modeling</th>
<th>Game Mastering Concepts</th>
<th>Collaborative Learning</th>
<th>Serious Games</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identified Gap</td>
<td>Player / Learner Modeling</td>
<td>Game Mastering in Serious Games</td>
<td>Game-based Collaborative Learning</td>
<td>Multiplayer Serious Games</td>
</tr>
<tr>
<td>Concept</td>
<td>Architecture Model</td>
<td>Game Master Interface</td>
<td>Adaptation Engine (AE)</td>
<td>Generic Solution</td>
</tr>
<tr>
<td>Implementation</td>
<td>Woodment: Competitive Serious Game for Collaborative Learning</td>
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</tr>
<tr>
<td>Evaluation</td>
<td>Collaborative Learning Game UX &amp; Functionality</td>
<td>Efficiency of Game Mastering</td>
<td>Acceptance (Target Groups)</td>
<td>Efficiency of Adaptation Engine</td>
</tr>
</tbody>
</table>

*Game Mastering in Serious Games*

*Collaborative Learning Game UX & Functionality*
# Roadmap

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<td></td>
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<td>Evaluation</td>
<td>Escape From Wilson Island: Serious Game for Collaboration and Communication</td>
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<td></td>
</tr>
</tbody>
</table>

- **Covered in 1st & 2nd Research Talk**
- **Covered today**
- **Future work (next year)**
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Concept and Architecture
- Research Questions
- Architecture
- Game Mastering Interface

Adaptation Engine
- Rule-based Adaptation
- Model-based Adaptation

Evaluation
- Game Master Frontend
- Game Mastering Effectiveness
- Adaptation Effectiveness

Summary and Outlook
Hypothesis:

„With a specifical support of teachers/trainers/instructors in collaborative multiplayer Serious Games, the learning outcomes of the learning group can be improved“

RQ1: What are typical tasks of instructors in collaborative Multiplayer Serious Games?

RQ2: What are necessary information and means of adaptation for instructors in order to perform these tasks in collaborative Multiplayer Serious Games?

RQ3: Do users have a better learning outcome in collaborative Multiplayer Serious Games, if instructors can support/lead/coach them in-game?

RQ4: Can instructor tasks and duties be automatized in order to support the instructor and to reduce the cognitive load on the instructor with a comparable effectiveness?
Architecture

Game Master

GM Toolkit

Info (runtime)

Input (pre-game)

Direct Adaptation (runtime)

Group State

LM IM PM

Adaptation Rules

Model-based Adaptation Engine

Rule-based Adaptation Engine

Game Facts

Collaborative Serious Game

Learner Group

Game World

Players

Interaction
Architecture

- **GM Toolkit**
- **Group State**
  - PM
  - LM
  - IM
- **Adaptation Rules**
- **Game Facts**
- **Model-based Adaptation Engine**
- **Rule-based Adaptation Engine**
- **Input (pre-game)**
- **Info (runtime)**
- **Direct Adaptation (runtime)**

- **Learner Group**
- **Collaborative Serious Game**
Architecture

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Direct Adaptation (runtime)

Group State

Model-based Adaptation Engine

Rule-based Adaptation Engine

Adaptation Rules

Game Facts

Learner Group

Collaborative Serious Game

Game World

Players

interaction

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Game Mastering Interface – 3D 3rd Person Game Components

Game Components

Game World
- Elements
  - Terrain
  - Static 3D objects
  - Interactable objects
  - NPCs

Players
- Parameters
- Avatars
- Attributes
- Inventories

Interaction
- Communic.
- Other

Learning Content

Game Mastering Interface

RQ2: What are necessary information and means of adaptation for instructors in order to perform these tasks in collaborative Multiplayer Serious Games?

**GM Interface**

- Camera : List<Camera>
- CameraPoints : List<Coordinate>
- GameParameters : List<Parameter>
- PlayerParameters : List<Parameter>
- PlacableObjects : List<GameObject>
- RemovableObjects : List<GameObject>
- MovableObjects : List<GameObject>
- NPCs : List<NPC>
- Actions : List<Action>

- placeObjectInWorld(objectType : GameObject, coordinate : Coordinate) : void
- removeObject(objectId : GameObject) : void
- moveObject(objectId : GameObject, targetCoordinate : Coordinate) : void
- triggerAction() : void

**Camera**

- view : [free, fixed]
- followPlayers : bool
- moveToObject : Coordinate : void
- moveToPoint(cameraPoint : Coordinate) : void

**Parameter**

- type : [bool, int, float, double, String]
- range : range
- value : string
- modify : bool

**Action**

- name : String
- description : String
- isTriggerable : bool
- trigger() : void

**NPC**

- NPCChat : bool
- PredefinedChats : List<Dialogue>
- Actions : List<Action>
- isMovable : bool
- moveNPC(target : Coordinate) : void
- triggerAction(action : Action) : void
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Input (pre-game)
Direct Adaptation (runtime)

Group State
Adaptation Rules
Game Facts

Model-based Adaptation Engine
Rule-based Adaptation Engine

Learner Group
Collaborative Serious Game

Game Master
Goal: Adaptation of game in order to

- improve motivation (gaming),
- learning behavior, speed, and success
- interaction processes (teamwork, communic., etc.)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbolic Rules</th>
<th>CBR</th>
<th>IMS LD</th>
<th>Agents</th>
<th>Experience Engine</th>
<th>Neural Network</th>
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<tr>
<td>Reusability</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
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<td>+</td>
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<tr>
<td>Adaptation of Players</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<td>Adaptation of NPCs</td>
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<td>Performance</td>
<td>+</td>
<td>o</td>
<td>o/</td>
<td>o</td>
<td>o</td>
<td>o</td>
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<td>Applicability</td>
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<td>o</td>
<td>o/</td>
<td>o</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Difficulty of Tweaking</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>o</td>
<td>0</td>
<td>-</td>
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<tr>
<td>Extendability</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>o/</td>
</tr>
</tbody>
</table>

Result: Symbolic Rules + Agents are best options

Figures: Comparison of Adaptation Mechanisms (Master Thesis Sebastian Ahlfeldt, 2012)
Rule-based Adaptation

Workflow
- GameFacts in a fact base
- Rules in a rule base
- Rules entered by Game Master
  - Before game
  - During game

- Adaptation Engine evaluates all rules periodically
- Using the game facts database
- And fires actions if their rules’ conditions become true
Rule-based Adaptation

After 10 minutes playing time and once the log hut is built the player should start to hunt for his food. Berries alone will not keep the hunger away long enough. The next tasks are harder than before.

With this Action it is possible to send a message to a player directly. You are able to specify the player by role, item it carries, the name or the placeholder "Player". If the placeholder is chosen, the message will be sent to the player the rule triggers.
Architecture

GM Toolkit

Direct Adaptation (runtime)

Input (pre-game)

Info (runtime)

Group State

Model-based Adaptation Engine

Rule-based Adaptation Engine

Game Facts

Adaptation Rules

Collaborative Serious Game

Learner Group

Game Master

Player's Game Interaction

Game World

Players

Interaction

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Model-based Adaptation

Goal: Optimization in terms of learning, gaming, and interactions

- Available adaptation mechanisms
  - Possible actions
  - Mutable Parameters

- Group Model
  - Player Model
  - Learner Model
  - Interaction Model

- Game Parameters
Adaptation Engine – Group Model

- e.g. after [Bartle1996]
  - Tracks gaming decisions / behavior
- e.g. after [Korossy 1999]
  - Tracks learning progress
  - Hierarchical tasks
- Tracks communication
  - Tracks interactions
  - Tracks group actions

Model-based Adaptation

Goal: Optimization in 3 dimensions: Learning, Gaming, Interaction

- Algorithm

1: Calculate $\text{Diff}(\Theta)$
2: $\forall a \in A: \text{Calculate } \text{Diff}(\Theta') \text{ with } \text{Diff}(\Theta') = \text{Diff}(\Theta \circ a)$
3: Let $\text{Diff}(\Theta'_{\text{min}}) = \text{argmin}(\text{Diff}(\Theta'))$
4: Let $a_{\text{min}} = a \in A \text{ with } \text{Diff}(\Theta \circ a) = \text{Diff}(\Theta'_{\text{min}})$
5: If $\text{Diff}'(\Theta'_{\text{min}}) < \text{Diff}(\Theta)$: execute $a_{\text{min}}$:

\[ \Theta: \text{world state} \]
\[ A: \text{set of all possible adaptations} \]

- Calculation of Diff

\[ \text{Diff} = \alpha \times \text{Diff}_L + \beta \times \text{Diff}_G + \gamma \times \text{Diff}_I \]

$\alpha, \beta, \gamma$: weighting constants; $\alpha + \beta + \gamma = 1$
## Model-based Adaptation

### Actions
- Each action associated with post-effects
  - Related player
  - Group

\[ a \in A = (s_p, s_{a_p}, c_p, c_{a_p}, i_p, i_{a_p}) \]

<table>
<thead>
<tr>
<th></th>
<th>Skills</th>
<th>Challenge</th>
<th>Player Model</th>
<th>Interaction</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Skill 1</td>
<td>Skill 2</td>
<td>...</td>
<td>Skill m</td>
</tr>
<tr>
<td>Action 1</td>
<td>+0.2</td>
<td>+0.0</td>
<td>-0.4</td>
<td>-0.2</td>
</tr>
<tr>
<td>Action 2</td>
<td>+0.0</td>
<td>+0.2</td>
<td>-0.3</td>
<td>+0.0</td>
</tr>
<tr>
<td>...</td>
<td>+0.0</td>
<td>+0.1</td>
<td>+0.0</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>-0.3</td>
<td>+0.0</td>
<td>+0.0</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>+0.4</td>
<td>+0.4</td>
<td>+0.0</td>
<td></td>
</tr>
<tr>
<td>Action x</td>
<td>+0.1</td>
<td>-0.2</td>
<td>-0.3</td>
<td>+0.0</td>
</tr>
</tbody>
</table>
Model-based Adaptation

Learning
- Goal: Sum up probabilities of not learned skills

\[ Diff_L(l_i) = \sum_{j=1}^{n} (1 - p_{i,j}) \text{ with } l_i \in L \]

= 0, if skill is learned

\[ Diff_L = \sum_{i=1}^{m} \sum_{j=1}^{n} (1 - p_{i,j}) \]

L: Learners
S: Skills
\( p_{i,j} \): Prob. that Learner i has learned Skill j

Wendel, V.; Göbel, S. & Steinmetz, R.: Instructor support through a model-based adaptation of Multiplayer Serious Games, in preparation for Ed-Media 2013
Model-based Adaptation

Gaming

- Sum up differences of challenge and player model

\[
\text{Diff}_G(L_i) = |1 - CH_i| + \frac{1}{4}|PM_A - PM_{A,i}| + \frac{1}{4}|PM_K - PM_{K,i}| + \frac{1}{4}|PM_E - PM_{E,i}| + \frac{1}{4}|PM_S - PM_{S,i}|
\]

with \( PM_X \in [0; 1] \); \( CH \in [0; 2] \)

\[
\text{Diff}_G = \sum_{i=1}^{m} \left[ |1 - CH_i| + \frac{1}{4}|PM_A - PM_{A,i}| + \frac{1}{4}|PM_K - PM_{K,i}| + \frac{1}{4}|PM_E - PM_{E,i}| + \frac{1}{4}|PM_S - PM_{S,i}| \right]
\]

<table>
<thead>
<tr>
<th>Learner 1</th>
<th>...</th>
<th>Learner n</th>
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<tr>
<td>CH</td>
<td>0.2</td>
<td>1.6</td>
</tr>
<tr>
<td>PM_A</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PM_K</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PM_E</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>PM_S</td>
<td>1</td>
<td>0.4</td>
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</table>

- Actions:
  - Tips, Help
  - Variation of gaming parameters

- Action always related to a goal
  - „Increase number of hidden treasures“ → Increase interest of \( PM_E \)
Model-based Adaptation

Interaction

- Goal: Sum up deficiency in criterias

\[
Dif f_i (l_i) = \sum_{j=1}^{n} |1 - c_{i,j}| \quad \text{with} \quad l_i \in L, c_{i,j} \in [0; 2]
\]

\[
Dif f_i = \sum_{i=1}^{m} \sum_{j=1}^{n} |1 - c_{i,j}|
\]

- Criterias to be defined
  - Resulting from expert interviews (Nov./Dec. 2012)
  - E.g.: # chats, sub-group formations, # collab. Tasks solved, loners

L: Learners
C: Criteria
\( c_{i,j}: \text{Prob. that Learner } i \ \text{fullfills criterion } j \)
Model-based Adaptation

Resulting term for Diff

\[
\text{Diff} = \alpha \sum_{i=1}^{m} \sum_{j=1}^{n} (1 - p_{ij}) + \beta \sum_{i=1}^{m} |1 - CH_i| + \frac{1}{4} |PM_A - PM_A_i| + \frac{1}{4} |PM_K - PM_{KI}| + \frac{1}{4} |PM_E - PM_{EI}| + \frac{1}{4} |PM_S - PM_{SI}| + \gamma \sum_{i=1}^{m} \sum_{j=1}^{n} |1 - c_{ij}|
\]

with
\(a, b, \gamma: \text{weighting constants}; a + b + \gamma = 1\)
\(L: \text{Set of Learners}\)
\(S: \text{Set of Skills}\)
\(p_{i,j}: \text{Prob. that Learner } i \text{ has learned Skill } j\)
\(CH: \text{Challenge}\)
\(PM_A: \text{Achiever}\)
\(PM_K: \text{Killer}\)
\(PM_E: \text{Explorer}\)
\(PM_S: \text{Socializer}\)
\(C: \text{Set of Criteria}\)
\(c_{i,j}: \text{Prob. that Learner } i \text{ fullfills criterion } j\)
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Summary and Outlook
Game Master Frontend (RQ 1/2)

**Instructor/Teacher/Trainer Tasks**

- Analysis
- Moderation
- Coaching
- Intervention
- Monitoring
- Guidance

**RQ1**: What are typical tasks of instructors in collaborative Multiplayer Serious Games?

**RQ2**: What are necessary information and means of adaptation for instructors in order to perform these tasks in collaborative Multiplayer Serious Games?
Game Master Frontend (RQ 1/2)

Planned study
- In collaboration with AVM (Gemeinnützige Gesellschaft zur Förderung der beruflichen Bildung, Rüsselsheim)
- in conjunction with Game Master study

Observation of Game Master behavior (actions performed) during gaming sessions
- Logged data about …
  - Communication, World manipulation, NPC control, Game Parameter Manipulation, Camera Movement
- Categorization of tasks in terms of observation/adaptation
  - By instructors
- Categorization of tasks in terms of learning/gaming/interaction
  - By instructors

Complementary interview with instructors
# Game Master Frontend (RQ 1/2)

**Instructor tasks - Example table** (numbers: learning / gaming / interaction)

<table>
<thead>
<tr>
<th></th>
<th>Communication</th>
<th>World manipulation</th>
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<th>Game Parameter Manipulation</th>
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<tr>
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<tr>
<td>←</td>
<td>Direct</td>
<td>Indirect</td>
<td>Place</td>
<td>Remove</td>
<td>Move</td>
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<td>Monitoring</td>
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<td>Moderation</td>
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<td>Guidance</td>
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<td>Coaching</td>
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<tr>
<td>Intervention</td>
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Game Mastering Effectiveness (RQ 3)

First implementation in Woodment – Focus on Learning

Evaluation in Autumn 2012 (RQ3 – part 1)
- In cooperation with AVM
- Students from vocational schools (cooks, metal industry) + 2 school classes
- 8-10 groups of 4-6 players (about 48-60 participants) + 60 pupils (2 classes)

Setup
- 3 groups: (only game, game + Game Master, control group)
- Logging of game success
  - Points achieved
- Pre-post-test of related knowledge
- Game Experience Questionnaire (MG)

Second implementation in EFWI – Focus on Collaboration

Evaluation in 2013 (RQ3 – part 2)
- In cooperation with AVM
- Students from vocational schools (cooks, metal industry)
- Number of participants open

Setup
- 2 groups: (only game, game + Game Master)
- Logging of game success
  - Points achieved
  - time until game solved
- Additional judgement by pedagoge
- Game Experience Questionnaire (MG)
Adaptation Effectiveness

Evaluation in second half of 2013

- Results from previous evaluations necessary for evaluation design
- Professional instructors (teachers / trainers) will have to be included
- Comparison of AE with non-AE
- Does AE relieve the instructor?
- Does AE reduce the cognitive load during Game Mastering?
Summary

- Importance of CSCL and chances through Serious Games
- Need for combination of CSCL concepts and Serious Games technology

- Identification of importance of the instructor
- Design of mechanisms for adaptation and monitoring
- Support of the instructor in game-based CSCL scenarios

- Analysis of instructor role and tasks
- Generic mechanisms for instructor support
- Model and Framework for Game Mastering in Collaborative Serious Games
- Adaptation Engine with Adaptation Algorithms
- Implementation and Evaluation in two own Serious Games
Outlook 4th year

Data collection / Evaluations

Analysis of evaluation data
- Game Master Frontend
- Game Mastering Effectiveness

Implementation of Adaptation Engine
- Model-based
- Rule-based adaptation

Evaluation of Adaptation Engine
- Evaluation methodology
- Data collection
Timeline

Evaluation

Game Mastering concepts

Concept

Prototypes

STAR

2009 | 2010 | 2011 | 2012 | 2013
Thank you!

Any questions?
Appendix 1: Own publications


Appendix 1: Own publications


## Appendix 1: Own publications

<table>
<thead>
<tr>
<th>Reference</th>
<th>Authors</th>
<th>Title</th>
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<th>Pages</th>
<th>Publisher</th>
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Appendix: References


V9

TODO

VWendel; 05.10.2012