A Method for Simulating Players in a Collaborative Multiplayer Serious Game

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Motivation

Scenario: Collaborative Multiplayer Serious Games
- Digital Educational Games
- Small Learner Groups

Design of collaborative Multiplayer Serious Games
- Game Design
- Integration of Learning Content
- Interaction between Players

Adaptation of collaborative Multiplayer Serious Games
- By a human instructor (Game Master)
- Automatically

Challenges
- Testing requires a multitude of players at many points during development process
- Often hard to get in academic settings
Motivation

Goal: Being able to simulate
- ... Realistic player behavior
- ... In terms of gaming, learning, and interaction

Contribution
- Concept for agent-based simulation of player/learner behavior in (collaborative) multiplayer (Serious) Games

Enables
1) Support at design stage
   - Feedback
   - Simulated Playthrough
2) Testing
   - Game Mastering mechanisms
   - Automatic adaptation algorithms
Approach - Architecture
Basic Definitions

Game Variable: \( v \in V \)
Action: \( a \in A \)
Trait: \( t \in T \)
Skill: \( s \in S \)
Interaction Skill: (teamwork, communication)
Player Goal: \( g \in G \) with \( g = (PI, K \subseteq S, GC' \subseteq GC, P' \subseteq P) \)
Player Interest: \( pi \in PI, pi^T = (pi_1, pi_2, \ldots, pi_n), pi_x \in [0; 1] \)
Goal Condition: \( gc \in GC: \) boolean expression using \( V' \subseteq V \)
Knowledge Precondition: \( K \subseteq S \)
Plan: \( p \in P, p = (A' \subseteq A, K \subseteq S, GC' \subseteq GC, w) \)
Approach – AI Player Model

Player Model

\[ PM = (T, f) \text{ with } f: \text{trait} \to [0; 1] \]

\[
PM^p = \begin{pmatrix}
t_0 \\
t_1 \\
\vdots \\
t_{n-1}
\end{pmatrix}
\]

Learner Model

\[ LM = (S, g) \text{ with } g: \text{skill} \to [0; 1] \]

\[
LM^p = \begin{pmatrix}
s_0 \\
s_1 \\
\vdots \\
s_{m-1}
\end{pmatrix}
\]

Interaction Model

\[ IM = (I, h) \text{ with } h: \text{skill} \to [0; 1] \]

\[
IM^p = \begin{pmatrix}
i_0 \\
i_1
\end{pmatrix}
\]
Approach – Agent Simulation

Listing  Agent Simulation
Perceive()  ▶ Receive game updates, i.e. update the set of variables \( V \)
  if currentPlan = null then
    Find_Suitable_Plan()
  else if currentAction! = null then
    if currentPlan.hasNextAction then
      Start_Next_Action()  ▶ Start execution of the next action of the current
    plan
    else
      Find_Suitable_Plan()
    end if
  else
    Execute_Current_Action()  ▶ Go on with execution of current action
  end if
Approach – Goal Rating

Listing  Find Suitable Plan

Require: $G, G_{\text{possible}}, P_{\text{possible}}$
for all Goal $g \in G$ do
    if all knowledge preconditions $K_g$ of $g$ met then
        if all goal conditions $G_C g$ of $g$ met then
            RateGoal($g$) $\triangleright$ rate the importance of goal $g$
            $G_{\text{possible}} = G_{\text{possible}} \cap g$ $\triangleright$ considering the current world state
        end if
    end if
end for

Sort $G_{\text{possible}}$ $\triangleright$ sort goals according to their rating
Let $g_0$ be the first element in the sorted list of rated possible goals $G_{\text{possible}}$
for all Plan $p$ in $P_{g_0}$ do
    if all knowledge preconditions $K_p$ of $p$ met then
        if all goal conditions $G_C p$ of $p$ met then
            $P_{\text{possible}} = P_{\text{possible}} \cap p$
        end if
    end if
end for

Sort $P_{\text{possible}}$ $\triangleright$ sort plans according to their weighting $w$
Let $p_0$ be the first element in the sorted list of plans $P_{\text{possible}}$
return $p_0$

$\text{RateGoal}(PI, PM) = \frac{\sum_{i=0}^{|T|-1} 1 - |t_i - p_i|}{|T|}$
Implementation – Escape From Wilson Island
Approach – Plan Example

<table>
<thead>
<tr>
<th>Goal Name</th>
<th>Improve Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>pi</td>
<td>{0.5, 0.5, 0.5, 0.5, 0.5}</td>
</tr>
<tr>
<td>K</td>
<td>{Gather Berries}</td>
</tr>
<tr>
<td>GC'</td>
<td>{saturation &lt;0.9}</td>
</tr>
<tr>
<td>P'</td>
<td>{EatBerries, GatherAndEatBerries}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plan Name</th>
<th>Eat Berries</th>
</tr>
</thead>
<tbody>
<tr>
<td>A'</td>
<td>{Action_EatBerry}</td>
</tr>
<tr>
<td>K</td>
<td>{-}</td>
</tr>
<tr>
<td>GC'</td>
<td>{Inventory.berries &gt;0}</td>
</tr>
<tr>
<td>w</td>
<td>1.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plan Name</th>
<th>Eat Berries</th>
</tr>
</thead>
<tbody>
<tr>
<td>A'</td>
<td>{Action_GatherAndEatBerry}</td>
</tr>
<tr>
<td>K</td>
<td>{-}</td>
</tr>
<tr>
<td>GC'</td>
<td>{-}</td>
</tr>
<tr>
<td>w</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Evaluation

Design
- Initial study to evaluate the soundness and correctness of the approach

<table>
<thead>
<tr>
<th>Ind. Variable</th>
<th>Variable Values</th>
<th>Dep. Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player model</td>
<td>[0,0,0,0,1],</td>
<td>Goal Achievement Times</td>
</tr>
<tr>
<td></td>
<td>[0,0,0,1,0],</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0,0,1,0,0],</td>
<td></td>
</tr>
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<td></td>
<td>[0,1,0,0,0],</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[1,0,0,0,0]</td>
<td></td>
</tr>
<tr>
<td>Learner model</td>
<td>All skills = 0</td>
<td>Goal Achievement Times</td>
</tr>
<tr>
<td></td>
<td>All skills = 1</td>
<td></td>
</tr>
</tbody>
</table>

Setup
- Five game sessions for each configuration
- Logging of game events and player actions
- Qualitative + Quantitative analysis
Evaluation

Results

- Qualitative
  - Player Agents behavior varied with different player models
  - Player Agents with high 'Explorer'-trait found bottles and berry bushes earlier
  - 'Achiever' built the log hut earlier on average, felled more palms and gathered more berries
  - Player Agents with higher skills tent to act more focused

- Quantitative

<table>
<thead>
<tr>
<th>Goal</th>
<th>All skills = 0</th>
<th>All skills = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BuildHut</td>
<td>37 ± 8[s]</td>
<td>18 ± 2[s]</td>
</tr>
<tr>
<td>BuildRaft</td>
<td>142 ± 24[s]</td>
<td>102 ± 19[s]</td>
</tr>
<tr>
<td>IgniteFire</td>
<td>312 ± 42[s]</td>
<td>221 ± 36 [s]</td>
</tr>
</tbody>
</table>
Evaluation

Discussion
- Player simulation worked very well for EFWI
- Player Model, Learner Model, and Interaction Model effects could be observed

Shortcomings
- A comprehensive study under laboratory conditions is required for further, more precise statements
- Player model differentiations too small due to limited gameplay variations
- Evaluation using other similar games for evidence about the genericity of the concept is required

Next Steps
- Integration of automatic adaptation mechanism
- Deeper evaluation of soundness using different games
Thank you! Any Questions?

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