Score-Based Recommendation for Efficiently Selecting Individual Virtual Agents in Multi-Agent Systems

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ABSTRACT

Controlling user-agent-interactions by means of an external operator includes selecting the virtual interaction partners fast and faultlessly. However, especially in immersive scenes with a large number of potential partners, this task is non-trivial.

Thus, we present a score-based recommendation system supporting an operator in the selection task. Agents are recommended as potential partners based on two parameters: the user's distance to the agents and the user's gazing direction. An additional graphical user interface (GUI) provides elements for configuring the system and for applying actions to those agents which the operator has confirmed as interaction partners.

CCS CONCEPTS

• **Human-centered computing → Graphical user interfaces**; **Virtual reality**;

KEYWORDS

Multi-Agent Systems, Recommendation System, External Operator

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1 INTRODUCTION

Embedding multi-agent systems (MASs), i.e., groups of embodied, autonomous, human-like virtual agents (VAs), into immersive virtual environments is a common approach to increase a scene's degree of realism. By means of predefined behavior scripts or semi-flexible artificial intelligence approaches, the VAs plan and perform their activities self-reliantly suiting the scenario's contextual focus. As such, they enliven the respective scenario.

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Immersing users into this setup increases the challenge of designing the VAs' behavior: besides socially constrained habits like visible reactions to the user's presence (e.g., [Bönsch et al. 2016]), individual VAs are required to be temporarily engageable into situation-dependent interactions by the user. Possible scenarios include training like virtual teaching, where a human teacher interacts with virtual pupils (e.g., [Lugrin et al. 2016]), coaching and rehabilitation.

For these simulations, the user-agent-interaction is often realized via Wizard-of-Oz to ensure adequate and situation-depend reactions of the involved VAs: a human operator controls the verbal and non-verbal behavior of the virtual interaction partners. To this end, different control elements are provided to the operator, typically combined in a GUI, as described, for instance, in [Lugrin et al. 2016].

To ensure natural behavior, the immersed users should not be aware of the external control. Instead, they should perceive the user-agent-interaction as natural and the involved VAs as reactive. Consequently, the operator has to rapidly decide which VA is addressed or will be addressed by a user in order to apply an adequate action to a suitable VA. However, this decision is non-trivial, especially for a large MAS. Thus, the operator has to be supported in the task of selecting individual VAs: first, to ensure an uninterrupted flow of interactions, and second, to avoid incorrect VA selections.

To address this issue, we present a score-based recommendation system anticipating the user's next interaction partners.

2 THE RECOMMENDATION SCORE

As illustrated, for instance, in [Bönsch et al. 2017], suitable criteria for narrowing down potential partners for a user-agent-interaction are based on the respective user's behavior: a per-agent score can be computed weighting user-centered metrics like the user's distance to the VA, the user's gazing direction relative to the VA, or the user's gestures. Based on this score it can be decided whether a VA is a potential interaction candidate for the next selection.

As a first approach towards the required selection support for the operator, we implemented a basic recommendation system taking into account two metrics: distance and gazing.

The *distance* score $DS_i \in [0,1]$ is computed using the Euclidean distance d_i between the user and the i-th VA. Thereby, a high score is assigned to VAs being close to the user, and a low score to more distant VAs, shown in Equ. 1:

$$DS_i = \begin{cases} 1 & \text{if } d_i \leq r_{min} \\ 1 - \frac{d_i - r_{min}}{r_{max} - r_{min}} & \text{if } r_{min} < d_i \leq r_{max} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

All VAs closer than r_{min} are automatically assigned a score of 1, all VAs outside r_{max} are ignored (score of 0) and in between both radii a linear dependency is used. This scoring is inspired by the personal space, a concept describing a protective zone around oneself, ranging from intimate, personal, social to public [Hall 1963]. Thereby the intimate and personal zone can be related to the area from the user to r_{min}, the social zone to the area between r_{min} and r_{max}, while the public zone can be regarded as everything more distant than r_{max}. For later extensions, we plan to test more scoring functions and to take the scene into account, e.g., by excluding VAs behind walls.

The *gazing* score $GS_i \in [0,1]$ is computed using the angle α_i between the user's gazing direction and the connection line of the user and the i-th VA. Thereby, a high score is assigned to VAs with a small deviating angle and a low score to quite lateral VAs, shown in Equ. 2:

$$GS_i = \begin{cases} 1 & \text{if } \alpha_i \leq \beta_{min} \\ 1 - \frac{\alpha_i - \beta_{min}}{\beta_{max} - \beta_{min}} & \text{if } \beta_{min} < \alpha_i \leq \beta_{max} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Again, we used three ranges: The first range between *zero* and β_{min} describes that the user looks either directly towards the VA or into its approximate direction. The second range between β_{min} and β_{max} describes a lateral positioning between user and VA scored by a linear dependency. The third range above β_{max} is scored with 0, as interactions are assumed to be favored face-to-face. For later extensions, we plan to test other scoring functions and to take the scene into account, e.g., by excluding VAs who are occluded by scene objects.

To compute the *final score* $S_i \in [0,2]$ per VA i, both scores (DS_i and GS_i) are combined as a ω-weighted sum, shown in Equ. 3:

$$S_i = \omega_{DS} \cdot DS_i + \omega_{GS} \cdot GS_i \quad \text{with} \quad \omega_{DS}, \omega_{GS} \in [0,1] \tag{3}$$

Based on S_i, the VAs are sorted in descending order. VAs assigned the same score are sorted alphabetically by name. To further support the operator, a threshold t can be used to ignore VAs with a score below t. Thus, the operator can concentrate on the most likely interaction candidates to confirm one or more as the next interaction partners.

3 OVERVIEW OF THE GUI

In order to support the operator in controlling the behavior and actions of the user's interaction partners, we provide the GUI shown in Fig. 1. The embedded control elements enable the operator to manually select individual VAs and to apply certain actions to them. To decrease the operator's workload, the recommendation system, described in Sec. 2, is integrated into the GUI as well, providing a list of recommendations as well as configuration elements for the scoring.

The GUI's upper part provides three camera views onto the scene, allowing the operator to keep track of all events in the scene and to select individual VAs as interaction-partners via clicking on the respective VA. The top left view renders the image which is seen by the immersed user. The view on the bottom left provides a bird's eye view onto the scene, in which the operator can manually pan and zoom. On the right side, a free roam view is given, in which the operator can move the camera freely. The latter two views present the user's position and orientation via a red triangle. Additionally, all camera views can be reset by buttons.

The GUI's lower part provides the control elements for the MAS. From left to right, we provide 5 logical units: (1) a list of all embedded VAs, stating which actions they are currently performing; (2) a list of

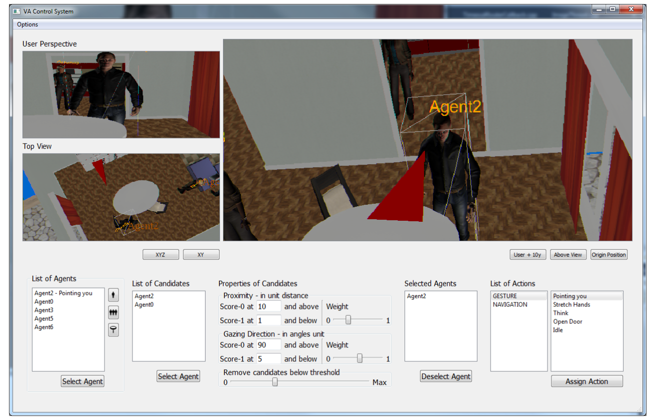

Fig. 1: GUI for the external operator containing a camera (top) and a basic agent (bottom) control system.

the VAs proposed by our recommendation system; From both lists, the operator can select individual VAs by clicking on the respective list entries; (3) control elements to set the parameters configuring our recommendation system; (4) a list of those VAs confirmed by the operator as interaction partners; (5) control elements to apply certain actions to the selected VAs. To interrupt these actions if needed, the operator can use the same control elements or further control elements embedded besides the list of all agents.

4 PRELIMINARY EVALUATION

In a preliminary test, 6 subjects took over the operator's role evaluating the functionality of the recommendation system. Therefore, they had to select the potential interaction partners in predefined scenarios providing static constellations of VAs and a hypothetical user.

We observed that, in general, the subjects were able to configure and use the recommendation system. However, during conclusive interviews several improvements for the GUI's design were suggested. Thus, even though the system provides only a very basic set of parameters yet, it already supports the selection task required for situation-dependent user-agent-interaction by an external operator.

5 CONCLUSION

We have presented a basic, user-centered and score-based recommendation system supporting operators in selecting the suitable VAs of a MAS for a situation-dependent user-agent-interaction.

In the future work, we plan to enhance our approach based on the user comments in the preliminary test and re-evaluate it. In a further step, we will evaluate the suitability of the selection based on the feedback of an actual immersed user.

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