Reactive Virtual Agents: A Viewpoint-Driven Approach for Bodily Nonverbal Communication

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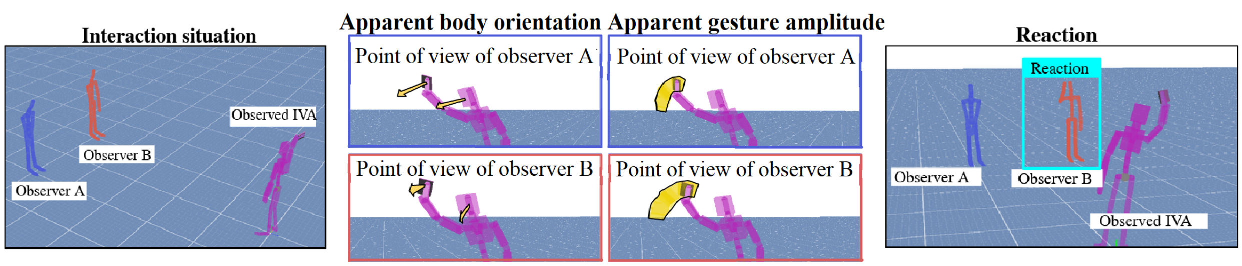

Figure 1: Waving case from left to right: two Intelligent Virtual Agents (IVA) – A and B – observe another one; visual motion features – body orientation, gesture amplitude – are computed on the observed IVA's motions from each viewpoint; B reacts

ABSTRACT

Non-verbal communication body cues are paramount to interact. In this preliminary work, we explore ways to let Intelligent Virtual Agents (IVAs) simulating nonverbal communication capabilities. We propose an approach to control IVAs' reactive behaviour from the analysis of other agents' apparent motions, in a situation of "observed" IVAs that act and "observers" that react. For that, first a viewpoint-driven analysis of the observed agent's motion is done, and then a synthesis of this analysis induces the observers' reaction.

CCS CONCEPTS

• **Computing methodologies** → **Simulation environments**; **Motion processing**; **Procedural animation**.

KEYWORDS

virtual agents, reactivity, animation, motion features, visual features

ACM ISBN 978-1-4503-8619-7/21/09.
https://doi.org/10.1145/3472306.3478351

ACM Reference Format:
Pierre Raimbaud, Alberto Jovane, Katja Zibrek, Claudio Pacchierotti, Marc Christie, Ludovic Hoyet, Julien Pettré, and Anne-Hélène Olivier. 2021. Reactive Virtual Agents: A Viewpoint-Driven Approach for Bodily Nonverbal Communication. In *21th ACM International Conference on Intelligent Virtual Agents (IVA '21), September 14–17, 2021, Virtual Event, Japan.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3472306.3478351

1 INTRODUCTION

Intelligent Virtual Agents (IVA) should be designed to perform realistic and expressive interactions [3] that convey emotions and express personalities [23, 26]. These are notably expressed by humans through nonverbal behaviours in everyday interactions [8, 12]. Thus, the ability to perform nonverbal communication is paramount for IVA design [6, 21]. Nonverbal communication, notably reflected by proxemics and kinesics [17], contributes to the social realism of IVA interactions. In this regard, user studies have been conducted to evaluate generative models of IVAs' expressive facial motions [11, 14, 22] or body motions [18]. These last ones in particular – divided into postures and gestures [5, 16, 19] – appear to be the key to expressivity in nonverbal communication between humans [2, 10], and with IVAs [1, 27, 29]. Ravenet et al. [24] proposed a model to generate bodily nonverbal communication motions from the agents' roles in a conversation and some social attitudes and norms such as group formations. Their results confirmed the benefits of such nonverbal cues for more expressive social virtual agents. In line with this, Oshita et al. [20] focused on the design and use of body postures for attractive IVAs, and Zacharatos et al. [28] analysed body gestures through motion features such as velocity, derived from Laban Movement Analysis, to link them to emotions.

Nonetheless, ensuring the expressivity of IVAs' actions is not the only challenge related to bodily nonverbal communication. IVAs should also embed the ability to react to humans or other IVAs through adapted bodily communication [4]. In the literature, few authors focused on this aspect. Garcia-Rojas et al. [13] proposed a reactive motion model for reflexes according to stimuli and human individual characteristics – catch or dodge a ball – from real human motions analysis, to improve IVAs' individualisation through the personalising of reactions. In the context of conflicts, Campos et al. [7] studied the link of the IVAs' perception of emotions through body, facial motions and speech with reactive behaviours triggering.

Relying on the perception-action loop involved during human interactions [15], this work introduces a new concept to design IVAs with reactive body motions based on a viewpoint-driven approach. We present a new paradigm for reactive behaviours simulation, based on the visual analysis of body movements. In this short paper, we focus on situations where the poses of all agents are known. However, the same idea can easily be extended to more complex scenarios where only partial information about the agents' poses is available. Our viewport-driven approach first analyses the "observed" IVA's motions from the viewpoint of the "observer" IVA, and then adjusts the observer IVA's reactions. Section 2 presents this approach, Section 3 a case study, and Section 4 our future work.

2 EGOCENTRIC VIEWPOINT APPROACH

Our main contribution is the development of a new approach to improve reactive interaction simulations – either between virtual agents or between real and virtual agents, based on the visual analysis of motions in nonverbal communication situations. Our overall approach is described in Figure 2 and encompasses two steps: an egocentric perspective step, which provides an analysis of the "observed" IVA's motions from the "observer" IVAs' viewpoint – the apparent motions as for them – and a synthesis step about this visual analysis to induce reactive motions of "observer" IVAs.

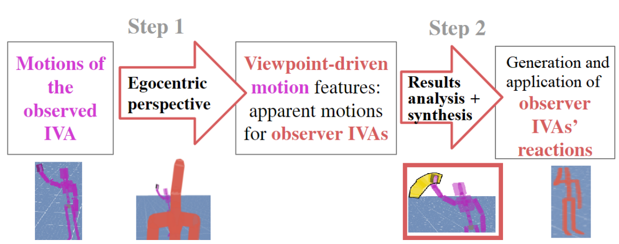

Figure 2: Our viewpoint-driven approach for IVAs' reactions

2.1 Visual motion features

Our first step consists in expressing the observed IVAs' motions in the egocentric viewpoint of the observer IVAs, fitting thus their visual perception of the current interaction between the IVAs. Our originality here is thus the reference frame that we use for the motion feature analysis: rather than considering motions as they are performed [28], we focus on how they are visually perceived, i.e. the motions – postures and gestures – as they are apparent from the observers' point of view. Here visual motion features are extracted from the positions and orientations of the observed IVA bodies, as they appear in the view space of the observers, using 2D projections. For example, we analyse the visual extension of the arms as they are apparent for the observers, rather than computing their absolute extension from the body current state in a 3D basis.

According to nonverbal communication motion classifications [5, 16, 19], we define here two categories of visual motion features, the apparent postures ones and the apparent gestures ones. Features related to posture are: *body orientation, body coverage, body self-coverage – amount of overlapping body parts on others – and body horizontal and vertical extension.* Features related to gesture are: *the amplitude and the velocity of the limbs used in a gesture.*

2.2 Synthesis of visual motion features results and reactive motions generation

The second step of our approach consists of analysing the results obtained about the visual motion features and in making a synthesis of it to induce reactive motions of the observers. Our key idea is to use the perception-action loop approach [15] for reactions [9, 15, 25], and to link the motion analysis from the observers' perception to the generation of reactive behaviours for them, in response to the other agents' body motions. Here we have addressed situations where this synthesis and generation step has been simplified and adapted for the specific case study presented in the next section, as a selection and then a triggering of a predefined reaction.

3 A CASE STUDY: WHO WILL WAVE BACK?

To exhibit our viewpoint-driven approach, we present an illustrative case study with the following nonverbal communication situation: an observed IVA waves at two other IVAs that will be the observers. This situation is shown on the left part of Figure 1. We aim to show that our approach can allow for the detection of which observer must react with a waving back gesture, by determining towards whom the observed IVA's waving motion is more directed to.

In this case study, in our first step we used one postural visual motion feature, the apparent body orientation – specifically the one of the head and of the waving hand, and one gesture visual motion feature, the apparent amplitude of the waving hand. The apparent body part orientation is computed as the difference of alignment between the observed IVA's body part orientation and the observer IVA's view orientation, $0°$ thus being the value associated to a maximal interaction between the two IVAs. The apparent amplitude of the waving hand is computed as the area covered by this gesture in the view space of the observer. The bigger the area, the more directed towards an observer the observed IVA's gesture is.

Figure 1 shows on its central part the comparison between the observed IVA's motions perception of the two observers from their viewpoint: the apparent body orientation is shown by yellow vectors, and the apparent amplitude of the waving hand by yellow areas. The following values have been computed over a 1.7sec waving motion, previously obtained through motion capture. In terms of posture, orientation results show that the observed IVA is more oriented towards observer B (head: 19.5° ± 4, hand: 20.6° ± 8) than observer A (head: 38.2° ± 4, hand: 40.4° ± 8). Similarly, waving hand amplitude results reveal that the waving is more extensively perceived by observer B ($5.47 \cdot 10^{-3}\%$) than observer A ($3.99 \cdot 10^{-3}\%$). According to these visual motion features results, a waving back reaction is triggered in observer B, as shown on the right of Figure 1.

4 LIMITATIONS AND FUTURE WORK

One limitation here is the omniscient comparative aspect that we used in our case study for the synthesis of reactive motions, which was adapted for such a predefined situation. We plan to develop a computational approach that could be used for environments where we only know partial information, and also for the creation of new reactive motion animations by modifying them depending on the computed features. In a multi-agents scenario, this would allow for the design of not fully predefined non-player character reactive behaviours, e.g. in games. Additionally, on more "spontaneous" cases, the observers' reactions should be independent and guided by visual thresholds over the viewpoint-driven motion features, instead of the omniscient point of view and agents' control used here. For such future work, threshold levels should be determined, e.g. through data about real humans' interactions, and also to manage the non-trivial issue of combining the results obtained from different features. Moreover, we could try to generalise our approach to scenarios with crowds. In such cases, body orientation and amplitude of moving limbs may not be considered as sufficient to induce a reaction, because of the crowd's effect on observers' perception: the agent's postural space in the observers' view space should be evaluated. Thus, in our approach it would consist in computing additional visual features such as horizontal or vertical body extension and body coverage. Finally, our viewpoint-driven approach aims to be applied for IVA - real agent interactions, in a virtual reality environment notably, with real-time tracking of user movements, where agents would be reacting to the embodied user.

ACKNOWLEDGMENTS

This work received funding from the European Union under grant agreement No 856879 (H2020 ICT-25 RIA PRESENT project), as well as the Brittany Region, project SAD-2019-REACTIVE, No 19023.

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