Semantic Representation of Individualized Reaction Movements for Virtual Humans

Alejandra García-Rojas, VRLab-EPFL
Frédéric Vexo, VRLab-EPFL
Daniel Thalmann, VRLab-EPFL

***Abstract*— Virtual Human (VH) creation aims to provide virtual characters with realistic behavior, which implies endowing them with autonomy in an inhabited virtual environment. Autonomous behavior consists in interacting with users or the environment and reacting to stimuli. Reactions are unconscious behaviors that are not often implemented in virtual humans. Frequently, virtual humans show repetitive and robotic movements which tend to decrease realism.**

To improve believability in virtual humans we need to provide certain level of individuality. This individualization is achieved by using human characteristics like personality, gender, emotions, etc. In this paper, we propose to use those individual descriptors as a basis for different kinds of reactions. Based on observation experiment on real people reacting, we analyze people's movements and identify different reactions. From this analysis we extract a list of simple movements; and when combining them it is possible to get several different movements. Therefore, we present a semantic diagram (ontology) to classify types of reactions by means of simple movements; and we describe the components involved in the reaction, such as individual descriptors, and virtual human controllers. For our showcase application, we synthesize simple movements using inverse kinematics techniques, and we show that by chaining individual parameters we can produce different reactive animations.

***Index Terms*— Animation, Motion analysis, Motion Synthesis, Semantic model, Virtual Human.**

I. INTRODUCTION

A realistic Virtual Human behavior lies in a good simulation of its autonomy. There are models of behavior that provide autonomous cognitive control[1], and a good perception of the environment [2]. This autonomy consists in self awareness and task performance. However, we believe that not unexpected movements, like reactions, can increase the realism in virtual characters.

Human reaction to unexpected events vary from one person to another. To achieve a good simulation of reactions we need to address several aspects of the process. The better way to understand and analyze this process is through observation and analysis. In this paper, we present an observation-based approach to stereotype reaction movements of the humans. This kind of approach has already been used to provide autonomous behavior to virtual humans [3].

We are interested to model the kind of reactions that require short time of response. As a consequence, our observation case study consists in a simple reaction movement: make people react to a ball thrown towards them. Reactions to this kind of situations vary in many different ways from one person to another; they also vary over time, it means that the same person will react differently to the same stimulus. This variation depends on the personality and internal state of each person at that moment.

The results of the case study analysis allowed us to stereotype movements. These movements were also decomposed in small movements that can be semantically described in terms of individual parameters such as gender, personality, emotion etc. Therefore, we focused on synthesizing and parameterizing the defined kind of movements, in order to be able to produce variations of the same movement. As we want to produce movements that are coherent, we made a classification of simple movements in terms the types of reactions and movement characteristics. This classification is made inside an ontology that also describes the virtual character as an individual. Therefore, we aim to use virtual human descriptors to set parameters of different kind of reactions. We have to point out that in this paper, we do not intend to predict the kind of reaction of a kind of person, but to provide different kinds of movements according to the assumption of individualities.

To reproduce these simple movements, we used inverse kinematics. This technique allows changing movement's settings according to the characteristics of the stimulus, such as direction, size or velocity. The way inverse kinematics, individual parameters and reactive behavior are related is presented in a semantic diagram (ontology). Based on this context, we built a system where virtual humans are able to produce a spontaneous behavior according to their internal information and external stimulus coming from the virtual environment.

The content of this paper is organized as follow: in section II, we present the related work about reactive motions. Then, in section III, we describe the case study of real people reacting. In section IV, we give a semantic representation of individual reaction behavior for virtual humans. In section V, we present the synthesis of movements using inverse kinematics. Finally, in section VI we present our conclusions and future work.

II. RELATED WORK

The simplest spontaneous behavior in human beings produced by external stimuli is the reflex. Reflexes are unconscious movements and are regulated by the nervous system. They can be considered as the basis of movements or even as the root of human movement. Implementation of reflex movements in virtual humans were already explored in [4]. They got inspired on the nervous system and used inverse kinematics for the implementation. They made virtual humans able to react spontaneously to stimuli, however this implementation is very limited to a set of movements in the virtual human's arm.

In game industry, reactive behaviors are very limited. The autonomous characters are not capable to provide coherent responses to users' actions. Intent to provide a realistic reaction system is presented in [5]. The authors created a relationships model in order to provide a background to the character, which helps them to react in an expected way. Their approach is based on social sciences instead of cognitive. However, this work provides a interesting behavioral model, it does not consider simple reaction where any background is needed, and a high level of cognition is not needed.

Reactive animations to stimuli are made using motion captured sequences. This is commonly found in battle or sport video games. The use of motion capture is useful when reaction are relatively limited to a group of movements. To be able to perform a realistic reaction, one needs a large database of motion captured movements and search for the most suitable one. Afterwards, it is possible to apply motion blending, dynamic constraints [6] or physical constraints [7] to make it the most realistic possible. Komura et al. [8] used motion capture mixed with momentum-based inverse kinematic. IK was used to keep the balance of the character.

In the approaches above, authors are dealing with the passive effect of an impact. This means that the character has been hit and they compute how he will fall down in a realistic way. In [9], this kind of work has been extended by making the arms of the character react in a protective way when he is falling down. These animations are physically realistic, due to the fact that they have been captured from real human movement. However, at the time to be coherent with human-like behavior, they are not so useful. They may need to have extra annotations in the animation database to be able to extract one that accomplish individual characteristics of virtual characters.

We believe that reaction movements, or any other kind of movement in virtual characters, have to give the impression of being alive; and for that some individualization should exist. Towards the synthesis of body gestures in Virtual Humans (VH), in [10] authors presented a behavior library based on MPEG-4 animations where reuse can be made depending on the content, but emotional expressions are not contemplated. Even if we can find the desired animation, we would like to have it with some variations to avoid repetitions or to adapt it better into an expressive context. Raouzaiou et al. have presented in [11] approaches to synthesize movements from video analysis. They have provided high level descriptors to communicative gesture animations, such as making waves with the hands, clap, etc.; they presented the possibility of enhancing animations with expressivity parameters applied to the joint angle values. This approach is considered only for a few hand movements and is implemented with forward kinematics, which makes the treatment of the animation very difficult.

In the next section, we present an experiment we made to analyze how different people's reactions can be. Then, we will present the resulting set of movements obtained form the analysis of videos.

Fig. 1. Videos of real people reacting to a ball thrown towards them.

III. Reaction Analysis

We can consider reactions produced by reflexes as primitive responses that protect our body from danger, and help us to adjust to our surroundings. The movement performed during a reaction depends on many factors. The most evident factors are the physical characteristics: gender, age, body constitution, etc. e.g. aged people have uncertain or slow reactions. Other less evident factors are the internal or psychological parameters of the person: personality, emotional state, etc. e.g. considering a person who has been frightened; if she is highly neurotic she might shout out very loudly as a reactive response.

A common way to model human behaviors is by means of the observation and analysis. We have conducted an experiment in which we make people react to a stimulus: a ball thrown towards them. We annotated their morphology to be able to make future classifications. Our sample was of 20 people of different gender, nationality and age. With a hidden camera we record the subjects; while they were answering a questionnaire, suddenly we throw a ball towards them. Some screen shots of videos are presented in the figure 1.

Afterwards, during the analysis of data and videos, we have noticed that some subjects do not move much at the time of reacting, others avoid the ball, others protect themselves, and so on. The results of this analysis was the identification of common characteristics in the reactive movements. We could distinguish 3 types of reactions: intercept, avoid, and protect. They are briefly described hereinafter:

Intercept to avoid danger by putting something in between, in this case the hands.

Avoid to move the body in the opposite direction where is the stimulus coming from.

Protect to cover a part of the body to avoid the impact (e.g. use the hands to protect the face).

Description	Intercept/reject	Protect	Avoid
Step towards stimulus position	X		
Step backwards stimulus	X	X	X
Knees flexion		X	X
Pelvis Displacement	X	X	X
Hands position in stimulus	X		
Palm Orientation to stimulus		X	
Palm Orientation against stimulus		X	
Rise Lower arm		X	
Arms extension			X
Column inclination	X	X	X
Column rotation	X	X	X
Hiding Head		X	

TABLE I

MOVEMENTS OBSERVED FOR EACH TYPE OF REACTION

The observed types of reactions performed by the people were indeed with different intensities or even mixed. To be able to make a synthesis of those reactions, we needed to generalize some types of movements for their classification. This generalization is, for example, the stress reaction or closing the eyes are intent of avoidance.

We consider that the differences in reactions came out because of external and internal parameters. In this case, the external parameters are the direction and velocity of the stimulus. Internal parameters are comprised in the individuality of the person. Therefore, according to the external information and internal state of a person (individuality), an evaluation process takes place and decides the movement to perform.

The sample we took for this test is too small to allow us to highlight relations between individual parameters and kinds of reactions. We may need to address some psychological studies to be able to establish a relationship. In this paper, we are not interested in providing a kind of reaction according to a given parameters, but in generating different kinds of reactions that can be parameterized according to people's individuality.

Therefore, we have analyzed the videos and identified some simple movements from people that composed the types of reaction described above. These simple movements are listed in the table I. As we can see, some of them are common within types of reactions, and others are specific to a type of reaction.

As we can notice, this movements by themselves do not mean anything; but when they are combined, and inside a context, the complete movement have a meaning. In the next section, we use a semantic representation to provide meaning to simple movements. This representation should consider the existence of the mentioned internal and external factors that will produce a combination of simple movements.

IV. SEMANTIC REPRESENTATION OF INDIVIDUAL REACTIONS

Semantic representations are usually distinguished by the use of ontologies, which aims at the specification of a conceptualization [12]. The exploitation of ontologies is present in many knowledge domains. In Computer Graphics, it has been explored for shape analysis[13] in order to exploit shape creation, processing and usage. Also in [14], an ontology of facial motion synthesis was presented to describe facial shape deformations in terms of emotional expressions. In a more general context, the creation process of virtual humans was presented in [15], where there is an intent of establishing a semantic layer to support virtual human construction going from the mesh to animated characters.

Virtual Humans, as part of virtual environment applications can be formally represented not only as a 3D shapes, but also as dynamic entities with multiple visual representations and functionalities [16]. This allows for dynamically scaling and adapting the object's geometry and functions to different scenarios. The same structure can be applied to model behaviors, where we need scalability and adaptability to implement and test models. The knowledge that we are modeling in this ontology is indeed application independent, and serves to formalize the results we obtained in our analysis.

In this section, we want to describe reactions in terms of the animation process for making individual reactive characters. To build this ontology, we start from finding concepts and relations among them. In our representation, we consider virtual humans that are attributed with the following features:

- Morphological Descriptor: describes the shape of the human body as human being; it has the properties weight, height, gender, age, etc.
- Individuality: describes parameters that can define the individuality of a person, like personality, emotional state, cultural background, etc.
- Body: For a virtual human the body is constituted by geometry and skeletal structure that is used to drive the animation. For our application we use H-Anim to describe the body.
- Behavior Controllers: they are algorithms used to produce behavioral animation. The class specifies the inputs required for the algorithm to work and the outputs (usually animation sequences or specific joint values) it is capable to produce.
- Perception Algorithm: algorithm that simulates sensorial elements in virtual humans, such as vision, hearing, etc.
- Reaction behavior: algorithm that simulates the evaluation process where, considering the virtual human attributes and the nature of stimulus, it will generate a kind of reaction.
- Inverse Kinematics: algorithms that provide a skeletal posture defined by specifying a target location to end-effectors. The joint angles of the control skeleton are computed so that the end-effectors reach their targets as close as possible.

Those concepts describe the virtual human in a general way, and the individualized description is taken into account for producing a reactive behavior. Another element we have considered in our representation, which is part of the virtual environment, is the stimulus description. Stimulus has properties by itself, such as position and orientation; and if it is moving, velocity and direction; and probably a level of danger. Those properties will influence the reaction of the virtual human. In figure 2, we present an ontology diagram to model virtual human features for an individual reactive behavior. This ontology is formalized using OWL language[1]. Relations

[1]http://vrlab.epfl.ch/∼alegarcia/VHOntology/reactionOnto.owl

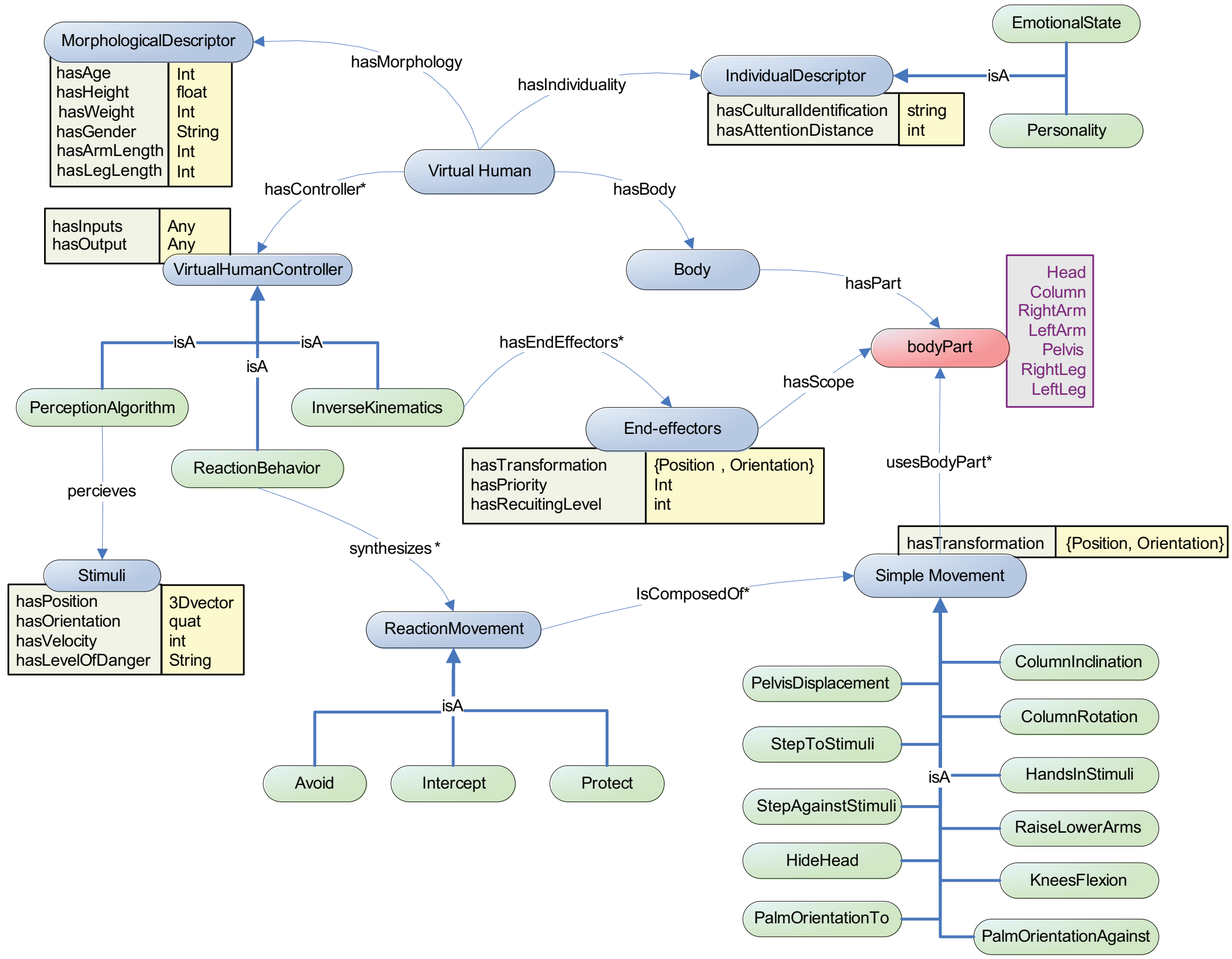


Fig. 2. Semantic representation of individual reactions for virtual humans.

between concepts are connected by thin arrows; for example, a *VirtualHuman hasbody*, *hasmorphology*, *hasindividuality*, etc.

In the ontology diagram, we show that classes can inherit from general ones. Subclasses are represented by a thick arrow that goes form the subclass to the superclass, and have the legend "isA"; which means, for example, that *Avoid* is A *ReactionMovement*. In the case of Virtual Human Controllers, we consider that they are algorithms that have inputs, make an evaluation according to the internal state of a virtual human and convey results in outputs. Thus, the classes *ReactionBehavior*, *PerceptionAlgorithm* and *InverseKinematics* are subclasses of *VirtualHumanController*. The reaction process of virtual human starts with the Perception Algorithm, which inputs are information from the environment and stimulus. The output of the perception is then, input for Reaction Behavior. In the same way output from Reaction Behavior is input for Inverse Kinematics controllers.

As our objective is the synthesis of reactive behavior, we will describe more in detail the semantic description we have developed for it. For the *ReactionBehavior* controller, the inputs are: stimulus, and morphological and individual descriptors of the character; and the outputs are inverse kinematics constraints, such as a distance to move, vector position of the hands, and so on. This controller makes also an evaluation to define the kind of movement to perform according to the inputs.

To semantically describe the decomposition of reactive movements in simple movements, we use this ontology to make classifications. The possible reaction movement can be of the three types defined in section III. These types of movements are composed by one or more simple movements. However, each type of reaction is constrained to a specific simple movement(s). For example, an avoid movement will not put the hands in the stimulus, or an intercept movement will not rise the lower part of the arm because it has to put the hands on the stimulus. These restrictions can be defined in the ontology to insure that type of movements are composed by the simple movements that describe them.

Inside ontology it is possible to define restrictions to constraint types of movements. *Necessary and Sufficient* restriction says that if an instance satisfy a given logical condition of a class, then it must be member of this class. In our case we want to express that if a reaction has some specific simple movement(s), then it must be part of given type of reaction. Thus, for each type of reaction we have defined the following necessary and sufficient restrictions:

Necessary and Sufficient restrictions:

$$Intercept \ \exists \ isComposedOf \ \ handsInStimulus$$

$$Avoid \ \exists \ isComposedOf \\ (columnInclination \ \cup \ columnRotation)$$

$$Protect \ \exists \ isComposedOf \\ (riseLowerArms \ \cup \ hideHead)$$

With these restrictions, we are saying that: Intercept movements must be composed of "hands in the stimulus"; Avoid movement must be composed of "column inclination"; and Protection movements must be composed of "Rise lower arms" or "hide head". However, types of reactions can have also other simple movements, but the classification expressed here serves to distinguish types of reactions.

With the definition above, we can select a type of movement and immediately know which simple movement is required. Afterwards, we may want to complement the movement with others. For this, we have to consider that not all movements can be mixed. We cannot use two simple movements that use the same body part and apply the same transformation. For example, we cannot put the hands in the stimulus position and at the same time raise the lower arm; but we can incline the column to the left and rotate it 20 degrees. To control this, we have added to *SimpleMovement* class, the property *hasTransformation*, which allows the values position or orientation. Here, we specify the type of transformation that is applied to each simple movement.

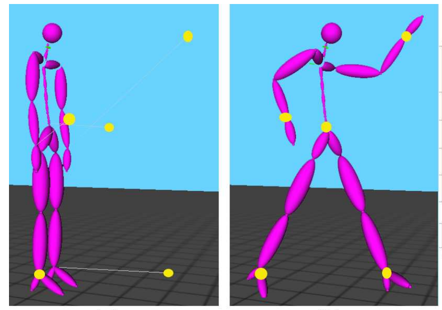
Based on this composition of movements and restrictions, we can mix some simple movements in order to produce different types of reactions. In the following section, we present the synthesis of simple movements using inverse kinematics.

V. Individual Reaction Movement Synthesis

The application is implemented using the VHD++ framework described in [17]. In this development tool, we can load characters with H-Anim structure that can use the IK implementation we are going to describe. VHD++ architecture provides a high-level control of the environment through python script modules. Using this interface, we can easily define higher level behaviors to lower level components. The implementation of the individual reactions is composed of two parts divided in the following subsections: how we synthesize simple movements using the inverse kinematics; and the reaction behavior controller, which considers individual parameters to produce different types of reactions.

A. Motion Synthesis Using Inverse Kinematics

To synthesize movements we have used the Inverse Kinematics library developed in [18]. This tool allows controlling more than one end-effector at the same time. It is possible to associate a distinct priority level to each effector to guarantee that the most important goals are achieved first. It also allows setting an engagement of the end effector joint with its parent joints in different levels. Moreover, we can treat the center of mass of the body as an end-effector to ensure the static



(a) (b)

End-Effector	Recruting Level
r_wrist_Position	3
l_wrist_Position	3
r_ankle_Position	2
r_ankle_Position	2
agentPosition	1

Fig. 3. Positional end-effectors (a), and the resulting posture when setting a goal position (b)

equilibrium of a figure [19]. Combining effectors and their associated weight and priority levels, we can simulate complex and believable synergistic postures.

As we mentioned, more than one end-effector can be set, we can set more than one position and orientation constraint on one arm with different weight and priority levels depending on the kind of pose we want to produce. This priority level goes form 1 to 10 where 10 is the maximum. For example, in protection motion, the orientation of the lower part of the arm is important, we can have the palm of the hands covering the face, but we can also have it in the opposite direction. There is a different movement meaning for each of those positions; covering the face could mean that the person is afraid, while the other one could be a defensive action.

Within this library, we can also assign different levels of joint recruitment. While controlling the position of the wrist for example, it is important to choose whether we want the spine to participate or not, using recruiting levels. This approach, presented in [20], allows to create a constraint to "recruit" all or part of the joints from its parent joint up to the root of the hierarchy. We can then easily define kinematics chains of varying lengths providing the user with more control over the final results. This level goes from 1 to 10, where 10 is the recruitment of all joints assigned in the IK controller. This property is useful to define the quantity of motion we want to propagate in the body. For example, in the avoidance motion we can move from the head to the entire torso. These movements may depend on the level of danger or the direction of the stimulus: if the level of danger of the stimulus is medium the movement will be propagated in all the entire torso, if it is high the character may step backwards.

Using this library to synthesis movements, we have created five positional end-effectors and five orientational for each of the following body parts: right leg, left leg, right arm, left arm and the spine up to the skull base. Through these effectors we are able to set actions at joint level to give end-effector position and/or orientation. To illustrate better the functionality of this library, in the figure 3 we present the created end-effectors (a), and a produced posture (b) when setting goals positions to the different effectors, accompanied by the list of parameters used.

Therefore, for each simple movement we have created a function that modifies the IK parameters in order to produce it. For example, "hands position in stimulus", is function of

	Description (Parameters)	Body Parts (transformation)
Lower Body	Step (direction, distance)	Right Ankle (P), Left Ankle (P)
	Knees flexion (distance) - in Y axes	Pelvis (P), Right Ankle (P), Left Ankle (P)
	Pelvis displacement (direction, distance)	Pelvis (P), Right Ankle (P), Left Ankle (P)
	Pelvis rotation (angle)	Pelvis (O), Right Ankle, Left Ankle (P)
Upper Body	Hands position in stimuli (stimuliPosition, stimuliSize)	Right wrist (P), Left wrist (P)
	Palm Orientation to stimuli (stimuliPosition)	Right wrist (O), Left wrist (O)
	Palm Orientation against stimuli (stimuliPosition)	Right wrist, Left wrist (O)
	Rise Lower arms (stimuliPosition)	Right wrist (P), Left wrist (P)
	Arms extension (distance)	Right wrist (P), Left wrist (P)
	Column inclination (direction, distance, recruitment)	Skullbase (P)
	Column rotation (degrees, recruitment)	Skullbase (O)
	Hiding Head (distance)	Skullbase (P)

TABLE II

PARAMETRIZATION AND SCOPE OF SYNTHESIZED MOVEMENTS

the stimulus position. In this case, we use the end effectors of the right and left hand and set the position where the stimulus will be. Here we may consider an aperture of the hands given by the size of the stimulus. This movement is illustrated in figure 4-left. Then, we can add other movement that does not uses the hands position, for example "column inclination". For this movement, we use the spine end-effector position. Its new position is function of a vector direction and a distance. A combination of "hands position in stimuli" and "column inclination" combination is presented in figure 4-middle. Finally, we can still add other movements to the lower body, for example the "knees flexion", where used end effectors are legs and pelvis for positioning the body; and the parameter is the distance that the pelvis has to go down. "Knees flexion" movent is integrated with the other described movements in the figure 4-right.

Fig. 4. Blending simple movements to create reactions: positioning the hands in the stimuli (left), Inclination of the column (middle), Knees flexion movement (right).

The types of movements identified in section III, are now used to synthesize the animation. In table II we present the list of movements we aim to reproduce using IK technique. These movements depend on some parameters, like a distance or direction; also they use some body parts and a type of transformation (P-position, O-orientation). This definitions were considered in the design of the ontology, as shown in the diagram in figure 2.

The way we implement simple movements is relatively easy. For example, for "Hands position in stimuli"we compute the vector position for the end-effectors of each hand. This position is the position of the stimuli at the moment when it is reachable by the virtual human arms, plus the separation of the arms according to the size of the stimuli. Another example is "Column inclination", where we compute the direction vector of the stimuli to get the direction of the movement which is perpendicular to the stimulus direction. The magnitude of the movement is function of the position of the stimulus; and the target position is applied to the spine end-effector. Other kinds of movements depend on a given distance, such as "knees flexion". We use this distance to descend the body and lift the end-effector of the legs (the ankle), but we may consider a limit distance, which in this case is the half length of the leg.

We have explained the process we follow to implement simple movements using IK. Movements are parameterized in order to be able to variate and combine them. In the next section, we present an example of Reactive Behavior controller that creates different types of reactions assuming behaviors in individual virtual humans.

B. Reactive Behavior Controller

For this demonstrative application, first, let us explain the perception algorithm we have developed. This algorithm tracks the position of the objects all the time. In this case the object is a ball that has an initial position and initial velocity. When the euclidean distance between the object and the character is less that the attention distance , we can say that the character can see the object. At this point the perception algorithm will compute a projection of the trajectory of the ball to know if the ball can be reachable by the arms of the character; this computation is given in formula 1.

$$|Pos_{vh}\ Pos_{object}| \leq vh.ArmLength \tag{1}$$

If the object is reachable, the character starts reacting.

The algorithm of reaction behavior we present is quite simple. We observed different kinds of behaviors in our case study, and we have hypothesized different kinds of reactions for our individualized virtual humans. This test considers three different characters: Brian, Lydia and Johanna. We have defined individual descriptors for each one inside the ontology. These instances are presented in figure 5. The morphology descriptor refers to the external physical aspect of the character. The personality definition is the five factor model [21], which is one of the most popular computational models of personality. The emotion is only defined by an emotional state assigned to the character at the moment of the reaction; and we have defined other kind of individualities, such as cultural identification and attention distance.

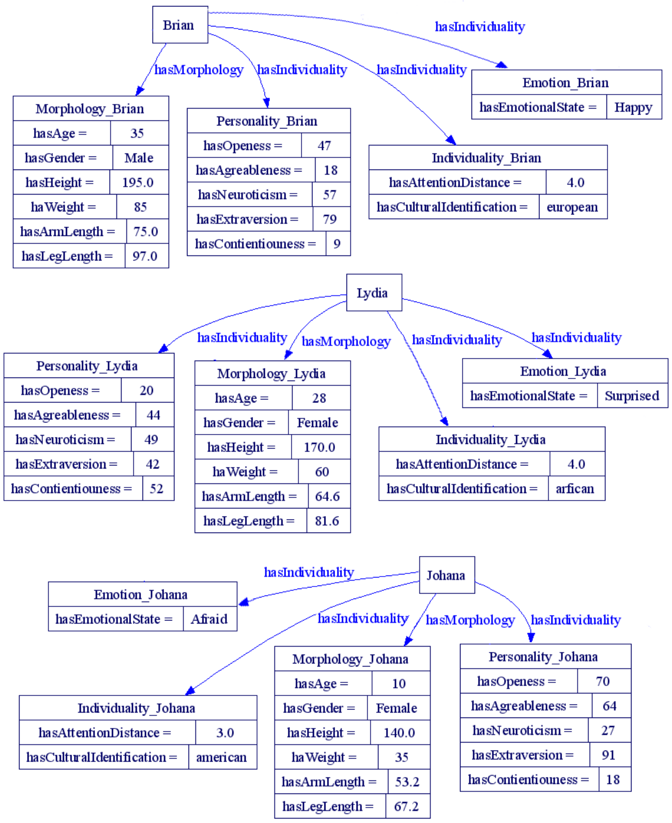


Fig. 5. Depicting Virtual Humans as individuals.

We have also defined properties of the stimuli, which is a ball thrown towards the character. These properties are direction and velocity, which are initial parameters for throwing it; level of danger, which is set as medium (not dangerous); and size equals to 13 cm of radius.

The emotional state produced in a person by a specific event could influence the kind of movement he may perform. If the character is afraid of an stimulus, he will contract the body; if it is surprised he will do an expansive movement, and so on. In this kind of movements, we are able to modify some characteristics such as amplitude or velocity, which are also factors that influence the variation of movements.

Therefore, the inputs of the reactive behavior controller are the individual descriptors and the properties of the stimuli. The algorithm chooses which kind of behavior the character will perform. Or algorithm is as follows:

```
If hasGenderType = Male:
    reactionType = "intercept"
If hasGenderType = Female:
    If age <= 15 :
        reactionType = "protect"
    else:
        reactionType = "avoid"

Set_base_movement(reactionType)

If stimuli_danger = HIGH :
    recruitingLevel = 7
else If stimuli_danger = MEDIUM:
    recruitingLevel = 5
else If stimuli_danger = LOW:
    recruitingLevel = 3

SpineInclination(recruitingLevel)
Add_movement(SpineInclination)

If hasEmotionalState = "afraid":
    Add_movement(kneesFlexion)
else If hasEmotionalState = "Surprised":
    Add_movement(armsExtension)
```

The first part of the algorithm chooses a movement according to the gender and age. Having the movement type defined, we can know from the ontology that intercept reaction implies to put the hands in the stimuli, protect implies to rise the lower part of the arms, and avoid implies an inclination of the column.

The second part of the algorithm provides other configuration of simple movements that will integrate the final one. It defines the recruiting level for the spine inclination according to level of danger of the stimuli. And finally according to the emotional state we add other movements, where we suppose that a person that is afraid may contract the body (e.g. flex the knees); and a person that is surprised will perform a broad movement (e.g. extend the arms). In figure 6, we present some results of combinations of movements by changing individual parameters and parameters of the stimuli.

We have shown that, once the kind of behavior is selected, we use the information of the stimuli parameters to compute the basic pose that the character may take. After that, we use character's individual traits and properties of the stimuli to add other simple movements to the base movement.

VI. Conclusion and Future Work

In this paper, we have presented how we synthesize different kinds of reactive movements by using a composition of simple movements. Selection of simple movements is the result of an observation experiment with the participation of real people. Observations allowed the identification of three kinds of reactions, and also the decomposition of movements in simple ones. A classification of movements and types of reactions are presented inside an ontology. This ontology also considers the individualization of virtual humans through morphological and psychological descriptors.

To synthesize reactions we implemented separately the simple movements using an inverse kinematics technique. Thanks to this technique, we can vary movements by changing parameters like priority of end-effector, recruitment of joints per end effector, and position and orientation. In the test application presented, we can model individualized kinds of reactions. The individualization takes place in a reaction behavior algorithm, which shows how individual descriptors and

Fig. 6. Screen shots of the different reactions in different individual characters.

properties of stimuli are taken into account to choose a type of reactions. Reactions are composed by a base movement, and by blending base movement with other simple movements we can create variations.

The main drawback of the achieved results, is the lack of a behavioral reactive solution that allow us to avoid hard coded reactions. Statistical approaches with awareness of individual descriptors can be considered. Some interesting research that can be applied is to be able to choose movements according with expressivity models of behavior. In interaction context with virtual agents, some models have been proposed to relate parameters of movements to behavioral expressions [22]. However, in this paper, some contribution has been done towards a semantic description to generate procedural animations.

VII. Acknowledgements

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Alejandra García Rojas Martínez graduated as Computer Scientist from Instituto Tecnológico y de Estudios Superiores de Monterrey in México. She received her M.T.D.I degree from the University Complutense of Madrid in 2004. Since January 2005 she is PhD student in in Virtual Reality Lab (VRlab) at the École Polytechnique Fédérale de Lausanne.

Dr. Frederic Vexo is currently research and teaching associate at the Virtual Reality Laboratory at the Ecole Polytechnique Federale de Lausanne, Switzerland. His research interests are multidisciplinary and include Virtual Reality, Human Machine Interface, Haptic, Human perception, Tele Operated System, Multimodal Adaptive Interface for virtual worlds, Semantic Virtual Environment and new services for graphic mobile devices.

Frederic Vexo has been Visiting Professor/Researcher at Monterrey TEC, Campus Toluca and Keio University and he was lecturer at the University of Reims.

Frederic Vexo is author of more than 50 papers in journals and international conferences in the fields of Virtual Reality, Human Computer Interaction, Robotics and Computer Graphics. He is member of several conference program committees and expert for different institution and companies.

He received his PhD in Computer Science in 2000 from University of Reims and Bachelors and Masters degrees from University of METZ. He also has contributed to various European projects.

Professor Dr. Daniel Thalmann is Professor and Director of The Virtual Reality Lab (VRlab) at EPFL, Switzerland. He is a pioneer in research on Virtual Humans. His current research interests include Real-time Virtual Humans in Virtual Reality, Networked Virtual Environments, Artificial Life, and Multimedia. Daniel Thalmann has been Professor at The University of Montreal and Visiting Professor/ Researcher at CERN, University of Nebraska, University of Tokyo, and Institute of System Sciencein Singapore. He is coeditor-in-chief of the Journal of Visualization and Computer Animation, and member of the editorial board of the Visual Computer and 4 other journals.

He is Program Cochair of CGI 2007 and Virtual Rehabilitation 2007, and the Conference Cochair of CASA 2007, SCA 2007, and ACM VRST 2008. He has also organized 5 courses at SIGGRAPH on human animation. Daniel Thalmann is member of Eurographics since 1980. He is member of the Stearing Committee of the Symposium on Computer Animation, a joint Eurographics-Siggraph initiative.

Daniel Thalmann has published more than 400 papers in Graphics, Animation, and Virtual Reality. He is coeditor of 30 books, and coauthor of several books including the "Handbook on Virtual Humans", published by John Wiley and Sons. He was also co-director of several computer-generated films with synthetic actors including a synthetic Marilyn shown on numerous TV channels all over the world. He received his PhD in Computer Science in 1977 from the University of Geneva and an Honorary Doctorate (Honoris Causa) from University Paul-Sabatier in Toulouse, France, in 2003.