The Virtual Environment - Another Approach

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ABSTRACT

In this paper the virtual environment, viewed as a multi-dimensional space, populated by entities which interact with each other is considered. In this universe an entity can trigger interactions with another entities or can be subject of such interactions. The environment's dynamics is determined by the information flow between its entities.

The proposed framework is based on the concepts of perception and action fields, which bounds the virtual environment's entities. More, the notion of informational link is introduced as a basis for inter-entities communication. Finally, we present the VR agent's architecture used in our developments.

Keywords

Virtual environment, virtual entity, virtual agent, fuzzy set, perception field, informational link.

1. INTRODUCTION

The main idea in virtual environment modeling is that the central element of any virtual environment is the user or, better, the entity through which the user expresses himself in a given context, its avatar. Consequently, in our approach, modeling a virtual environment means to identify the user's permitted actions in that environment and the way in which the environment's component entities give feedback to the user's actions.

The user sense the environment's entities feedback by the means of its receptors. At this level, the received information pass through a virtual perception filtering, according to its degradation accuracy [Hefc97]. Another transformation takes place at the level of user's/avatar's *brain*, according to the level of interest in the received information, based on the user's focus. All these, are used by the user/avatar in processing sensations into perceptions, bases of its reactions, according to its architecture (cognitive, reactive, etc).

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2. THE ENVIRONMENT

In the following sections, inspired by the human perception mechanisms, we will introduce, adopting a fuzzy approach, the virtual environment as the union of all perception (***nimbus***) and emission (***aura***) fields of the entities [Sing99] which populates the environment. The environment evolution is based on informational links established between these entities, which are looking to achieve some specifically tasks.

Informational space

Let us consider $\Im$ the set of available perceptions of the entities of a virtual environment. An element T belonging to this set is called ***generic type***. The $\Im$ set includes visual type, audio type, haptic type or any other type of information representation in communication between entities.

Let $S^{<T>}$ be the set of information of a generic type T. By $s^{<T>}$ we will note any element s of this set, $s \in S^{<T>}$. For example, considering T = **visual**, an element $s^{<visual>}$, so $s \in S^{<visual>}$, could be a *geometric* object having a certain *color*. Here *geometry* and *color* attributes are properties of $s^{<visual>}$.

Let us consider any visual element be defined as a pair $(g,c) \in \boldsymbol{G} \times \boldsymbol{C}$, where $\boldsymbol{G}$ is the set of geometric objects, introduced as sets of points in an Euclidean (or homogeneous) coordinates system, or as parameterized primitives, etc, and $\boldsymbol{C}$ is the colors space specified as one of the systems RGB, HSV, or HLS [Fole93].

Furthermore, let us consider $s_1,s_2 \in S^{<visual>}$, $s_1 =(g_1,c_1)$, $s_2 =(g_2,c_2)$. We define the sum of elements in $S^{<visual>}$ by $s_1 + s_2 = (g_1 + g_2, c_1 + c_2)$, where g_1+g_2 represents the regularized Boolean union between geometric objects, and c_1+c_2 is the colors composition.

We will note by Γ the set of pairs $\alpha = (\alpha_G, \alpha_C) \in M_4^{t3d}(R) \times \text{RGB}$, where $M_4^{t3d}(R)$ is the set of geometric transformations matrices, and RGB is the $[0,1]^3$ color system representation. Then Γ will act on $S^{<visual>}$ as follows: $\Gamma \times S^{<visual>} \to S^{<visual>}$,

$(\alpha, s) \to \alpha \times s$, where $\alpha \times s=(\alpha_G \times g, \alpha_C \times c)$,

where $\alpha_G \times g$, and $\alpha_C \times c$, are defined as follows:

$$\alpha_G \times g=\begin{pmatrix} \alpha_G 00 & \alpha_G 01 & \alpha_G 02 & \alpha_G 03 \\ \alpha_G 10 & \alpha_G 11 & \alpha_G 12 & \alpha_G 13 \\ \alpha_G 20 & \alpha_G 21 & \alpha_G 22 & \alpha_G 23 \\ \alpha_G 30 & \alpha_G 31 & \alpha_G 32 & \alpha_G 33 \end{pmatrix} \times \begin{pmatrix} x_g \\ y_g \\ z_g \\ 1 \end{pmatrix}$$ and

represent a geometrical transformation, and

$\alpha_C \times c=(\alpha_{red}, \alpha_{green}, \alpha_{blue}) \times (red_c, green_c, blue_c)= (\alpha_{red} red_c, \alpha_{green} green_c, \alpha_{blue} blue_c)$, which represent some color variation.

The set $S^{<visual>}$ with the previous defined operations will be called ***the space of visual information*** on Γ, or shortly, ***the visual space***.

Generally, a set $S^{<T>}$, together with the operations similar to those previously defined on some Γ, will be called ***the space of generic type T information*** on Γ, or shortly, ***the informational T-space***, and *T* will be called the ***informational dimension*** of S.

Let us now consider a set $\{e_i\}_{i=1,n}$ of elements from $S^{<T>}$. We will say that $\{e_i\}_i$ forms a set of generators for $S^{<T>}$ iff for every $s^{<T>}$ there exist $\alpha_i \in \Gamma$, i=1,n such that $s^{<T>} = \sum_{i=1,n} \alpha_i \times e_i$.

For an element (generator), $e \in S^{<T>}$ for instance, we will call the ***subspace of $S^{<T>}$ generated by e***, and we will write $S_e^{<T>}$, the set of all elements $s \in S^{<T>}$ of the form $s = \alpha \times e$, where $\alpha \in \Gamma$. In other words, if we consider an ordinary element of visual space $e^{<visual>}=(g, c)$, the visual subspace generated by *e* is the set of elements that can be expressed by $(\alpha g, \beta c)$, where $(\alpha,\beta) \in \Gamma$.

In the informational space $S^{<T>}$, we will express the emission and reception fields of our entities, according to Zadeh [Zade75], by the means of the following fuzzy subsets:

$S^{<T>}_R(P)=\{s \in S^{<T>}/R(A(s))=P$, where A is the implied attribute of T, by P$\}$.

The aura

We define as *aura* (or emission field) of an entity *A* in $S^{<T>}$ corresponding to an attribute $attr^{<T>}$ of the generic type *T*, the subspace in which this attribute is accessible to the entities of the virtual environment. We will note this subspace by $A_{attr}^{<T>}$. For example, the geometric aura of an object is its geometric shape.

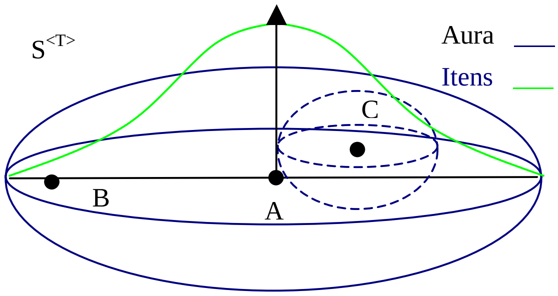

Figure 1. The aura of the A entity's attribute with its intensity variation.

For our purposes, we will consider as informational auras associated to attributes of a generic type *T*, spherical or rectangular domains, centered on the object position. Here, the variation of attribute intensity directly influences its perception by entities placed in *A*'s neighborhood. This intensity will be noted by $itens_{attr}^{<T>}(v\,;attr)$ and defined as follows :

$itens_{attr}^{<T>}(v, attr) : \Re \to [0, k]$, where

$$itens_{attr}^{<T>}(v; attr) = val(attr) \cdot e^{-\frac{v^2}{a^2}} .$$

Here $k=val(attr)$ is the maximum value of the attribute, as it is emitted by its owner, the A entity (see the figure 1), *v* is some distance (not necessary Euclidean) between the owner A and the user of the attribute, and *a* is the attenuation factor. If we consider Γ as the real interval [0, *k*], the aura of the attribute $attr^{<T>}$ is included in the subspace generated by *attr* on [0,*k*].

The nimbus

Let us consider two entities, A and B, between which was established an informational channel of the generic type *T*. We call *nimbus* (or perception field) of entity A in $S^{<T>}$ the fuzzy set, noted by $N_A^{<T>}$ and defined as $N_A^{<T>} =\{ x \in \Re^3 \mid \mu_A^{<T>}(x) > 0 \}$ where $\mu_A^{<T>}(B) = trans_A^{<T>}(v; long_A^{<T>}(u)) : \Re^3 \to [0,1]$.

As in the figure 2 is shown, $long_A^{<T>}(u)$ represents the *longitudinal variation with distance* of the perception accuracy of the T type information for an entity A (see visual accuracy). This function gives us the maximum value of perception in the immediate neighborhood of the perception direction.

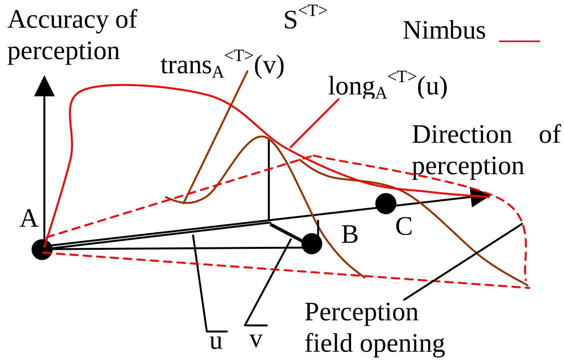

Figure 2. The nimbus (perception field) of an entity A

On the other hand, $trans_A^{<T>}(v;k)$ gives us the *lateral degradation of accuracy* in the perception field of the T type information: $trans_A^{<T>}(v;k) : \Re \to [0,k]$

$trans_A^{<T>}(v;k) = k \cdot e^{-\frac{v^2}{a^2}}$ where $\mathbf{k}$ is the maximum value, reached for $\mathbf{v}=0$, corresponding to the objects placed along the direction of perception, near the subject of perception focus.

The longitudinal variation of perception, determined by focusing on an object, from a set of objects placed in the immediate neighborhood of the perception direction, and produced by the variations of focusing, can also be determined by a Gaussian function with a small attenuation factor and a very rapid gradient from/to zero. In fact, $trans_A^{<T>}(v;k)$ can be used locally, for all the objects placed near the focused zone, as an accuracy of perception measure.

Both, the nimbus and auras of an entity in an informational space, can be modeled with any functions, well defined, particularly, interpolation, step functions, etc.

The T-informational shape

The informational dimensions of the entities are materialized by their attributes, spread in their environment. The propagation of attributes is realized either explicitly or implicitly, i.e. with or without special mechanisms for displaying their variations. Let us consider that the entity A owns a set of attributes $\{x_i\}_{i=1,n}$ of generic types T_i, $i=1,n$. In our approach the T_i-informational auras and nimbuses associated to each attribute completely define the entity from the structural point of view. The aura of an attribute constitutes the attribute's ***action domain***. The nimbus of an attribute is the attribute's ***activation domain***. Meanwhile, the aura and nimbus notions will be used in conjunction with entities.

A generic type T attribute can have associated an action domain and/or an activation one. An attribute with its domains (action and activation) is called ***T-informational shape***.

The T-informational shapes which have only the action domain are called ***producer shapes*** and denoted as a triple $< x, T, A_x^{<T>} >$. The T-informational shapes which have only activation domain, will be called ***consumer shapes*** and noted as a triple $> x, T, N_x^{<T>} <$. A producer shape which is also a consumer one, eventually with an informational dimension switch, is called ***translator shape***, and noted as the tuple $> x, T_{in}, N_x^{<Tin>}, T_{out}, A_x^{<Tout>} >$.

The T-informational link

Between two informational shapes of complementary type, let's say x consumer and y producer, we can establish a unidirectional informational link from y to x in the space $S^{<T>}$ iff $x \in A_y^{<T>}$. In such a case, we note $\mathbf{xLI^{<T>}y}$ and we say that ***x is in T-informational link with y***.

The ***measure of the informational link*** is given by:

$$xLI^{<T>}y = \mu_x^{<T>}(y) \times itens_y^{<T>}(x).$$

In other words, this measure is given by the intensity of informational signal, emitted by y and received by x, multiplied with the interest level of the receiver x in the information of y. This interest level is expressed by the position of the emitter y in the perception field of x, related to x's focus. This way, we can say that with every intensity variation of information a scaling operation in the perception field is also produced.

Even if it is not an order relation, being reflexive, anti-symmetric, and anti-transitive, $LI^{<T>}$ permits us to obtain a characterization of the fuzzy set of perceptions of an entity in the T informational dimension. With $LI^{<T>}$ we are able to *render* the link dynamics between entities, modeling the real world behavior.

We define a ***virtual environment*** as a set of T-informational shapes, in a well defined organization, with T-informational dynamics link between them.

3. THE VIRTUAL ENTITY

The proposed virtual environment model is inhabited with virtual entities which correspond to objects from the real world. The "meaning" of each virtual entity is its associated real object. For each real object attribute which is considered essential from the modeling point of view there is a corresponding informational shape. The attribute will be the meaning of the associated shape. In our approach, the ***virtual entity*** is the set of all informational shapes $\{F_i\}_{i=1,n}$, $n \geq 1$, which complete its meaning (see the figure 3).

As we have shown in the previous section, between the shapes of entities there are informational links. If the link is established between the shapes of an entity, the link will be called ***T-intrinsic link***, otherwise, the link will be ***T-extrinsic***.

Let us consider A and B two distinct entities with their sets of informational shapes $\{F_{A,i}\}_{i=1,n}$, $n \geq 1$, respectively $\{F_{B,j}\}_{j=1,m}$, $m \geq 1$. If there are at least two shapes $F_{A,i}$ and $F_{B,j}$ in *T*-informational link (T-extrinsic), then the entities A and B are in T-informational link.

By varying the importance of T-informational links categories, either intrinsic or extrinsic, we can obtain different types of "*psychological profiles*" for virtual entities. For example, in the case of a selfish entity, the T-intrinsic links are more important than the T-extrinsic ones.

The entities can be organized in groups, and may be further specialized in receptors and effectors.

A *receptor* is a detector of stimuli in different informational spaces, while an *effector* realizes shape modifications by means of the entity's actions in the virtual environment.

4. THE VIRTUAL AGENT

In order to model a virtual agent we use entity groups. The entities may be combined in order to produce complex aggregations, themselves entities. When receptors and effectors are involved in such an aggregation, the aggregated entity is a ***virtual agent*** (Figure 3), also called ***VR agent***.

In every moment of its life, the state of the virtual agent is given by the values of its attributes which are the generators of its informational shapes. The modification of the shape values may be initiated by the reception of an external stimulus such as a change in environment followed by the emission of internal stimuli. Based on these stimuli, the receptors generate perceptions which, in turn, will activate the decisional component, which will send orders to the effectors.

Suppose that the agent, *Ag*, have *n* receptors, $>r_i, T_i, N_{r_i}^{<T_i>}<$, $i=1,n$, and in its virtual environment, *Ve*, there are some stimuli, launched by the agent himself, and/or other agents/entities, noted by $St=\{<s_j, T_j, A_{s_j}^{<T_j>}>\}_{j=1,m}$. The measure of the *T*-informational link between *Ag* and *Ve*, containing *St*, for $T = \{T_i\}_i \cup \{T_j\}_j$, is given by:

$$Ag\ LI^{<T>}\ Ve = \sum_{i=1}^{n} \sum_{j=1}^{m} r_i\ LI^{<T>}\ s_j\ .$$

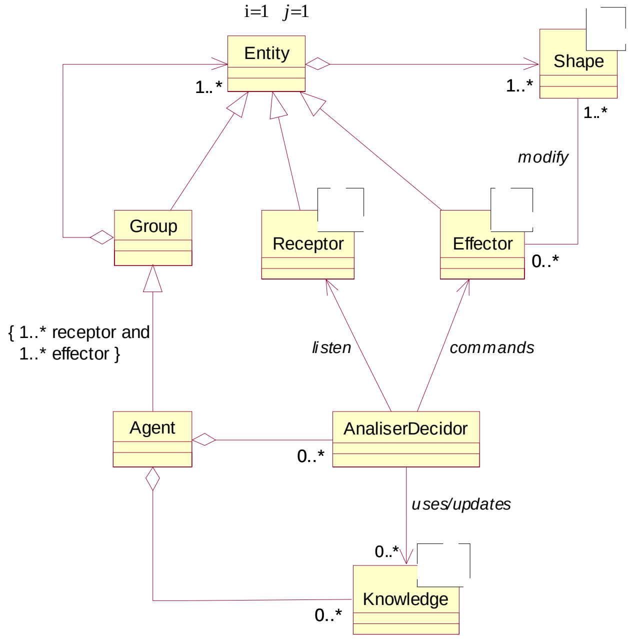

Figure 3. The virtual agent architecture

The knowledge, as resource or informational storage, is internal to the agent. It represents the agent's world model. Other categories of information as agent objectives, perceptions, sentiments can be modeled, as well.

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