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The Implementation of Spatio-Temporal Graph to Represent Situations in the Virtual World

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***Abstract*—**In this paper, we develop a Spatio-Temporal graph as of a key component of our knowledge representation Scheme. We design an integrated representation Scheme to depict not only present and past but future in parallel with the spaces in an effective and intuitive manner. The resulting multi-dimensional comprehensive knowledge structure accommodates multi-layered virtual world developing in the time to maximize the diversity of situations in the historical context. This knowledge representation Scheme is to be used as the basis for simulation of situations composing the virtual world and for implementation of virtual agents' knowledge used to judge and evaluate the situations in the virtual world. To provide natural contexts for situated learning or simulation games, the virtual stage set by this Spatio-Temporal graph is to be populated by agents and other objects interrelated and changing which are abstracted in the ontology.

***Keywords*—**Ontology, Virtual Reality, Spatio-Temporal graph.

I. Introduction

THE various situations in the reality are keys to make a virtual world to be natural [1], [2]. These situations are formed integrating interaction among objects in the virtual world and external environments as its conditions. The representation of the temporal dimension is important design elements for a multimedia representation upon consideration of objects and its behaviors and phenomena[3], [4]. The virtual residents adequately deal with fluxional changes which rest on various estimations about the situations in the virtual world. The time and space which consisting of historical contexts in the virtual world is elemental parts and must first be defined for the existence of objects. Because the changing and constructing and destructing property process according to the occurrence of events is occurred based on time and space, S-T graph (Spatio-Temporal) providing logical Spatio-Temporal coordinates which lay the implementation of historical contexts. The aim of this paper is implementing S-T Graph which indicates the time and space of the situations in the virtual world. Especially, we strive for the natural implementation of S-T Graph so it could intuitionally infer about complex situations that are linked to numerous information.

This paper is organized as follows. Section II reviews related research. Section III reviews situation representation using S-T graph based on ontology. Section IV introduces the implementation about a story of robbery with the multi-perspective screens. Section V conclude and future research directions.

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II. Related Research

A. Ontology

In the field of artificial intelligence, it is the key of the ontology that defining concepts and link to each concepts through the relations so a computer recognizes and infers using the ontology. Early 1990s, there was a necessity of the knowledge-based system in order to the agents resolve problems by interactions among themselves in distributed computing environment. The knowledge-based agent's communication language using KQML(Knowledge Query and Manipulation Language) had presented for the necessity [5]. Because the ontology varies for the purpose of user, there are numerous forms of the ontology. The reason why there are many different forms of the ontology is that each computer has its own structure to run applications. We classified the knowledge structure following four elements as its category, entity, relation, activity, pure concept [6]. Therefore, each specialized models of data structures needed to be preceded due to the data models for each class have different forms.

B. Spatio-Temporal Data

The importance about efficient management of space objects became important and the research for the spatio-temporal database system is under active discussion according to a variety use of space database system [7]. The spatio-temporal data is a record of object's space changes along with the flow of time. For example, mobile phone's use of information and traffic reports and path of the typhoon are typical spatio-temporal data.

The most of those spatio-temporal data are based on the E-R model(Entity-Relationship model) and UML(Unified Modeling Language) and are studied for the system development of moving objects. The SOLAP(Spatial On-Line Analytical Processing) is a typical spatio-temporal database and has a point that both representations are possible to use maps and diagrams [8].

However, such systems are limited to the functions and actions and even not able to present the meaning of changes according to the flow of time. The S-T Graph's data model should be created based on the spatio-temporal database. This could store the spatio-temporal data through the database system which process the stored data for the estimation. The basic database system is subject to the design and specify for the S-T Graph.

III. Situation Presentation

In this implementation of virtual world simulation, the ontology is used as a cast to create individual objects and as a structure to present an agent's knowledge at the same time.

Concepts which compose the virtual world could be geared towards hierarchical structures and consist of each other concepts to mutuality based on the hierarchy [9], [10]. The concept is determined by its properties such as descriptive attributes, components, functions, constraints. The ontology is made up of a hierarchical class structure shown in Fig. 1.

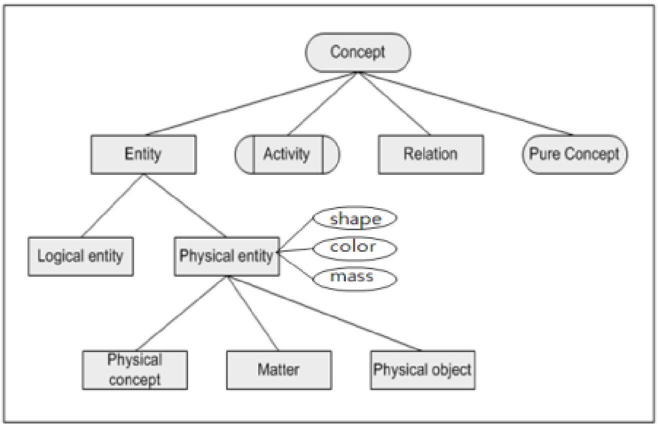

Fig. 1 The ontological Class Hierarchy

Each virtual inhabitant in the virtual world has his or her own concept. These individual concepts composing the virtual world are implemented by abstraction of the Instance graph and S-T graph and multi-media reality. The S-T graph, we use in this implementation, consist of physical entities based on the ontology as its elements. The physical entities stand for all physical objects existing in spatio-temporal space and include objects, matters and physical concepts. The Matter, including composite material, is an element composing the virtual world and doesn't disappear but changes its shape and state. The physical object consists of one or more matters and objects and returns to the state of the matter of ingredients when it loses its unique properties. The physical concept has physical properties like air, energy, light but it can't be perceived by the sense.

The physical concept doesn't occupy a space unlike the physical objects and matters. It is called 'binding' that an existing instance from the physical entity occupies a point in the S-T graph. An existence of these physical entities in the virtual world means that a relevant instance positions at the S-T graph. The physical concept is based on an entities' physical position and the flow of time but the state about related entities' relations is presented in the Instance graph. In the other words, the existence and state of all entities and relation change with the result of events which occurs along with the time. In Fig. 2, S-T graph consist of a layer corresponding to Physicality, Logicality, conceptuality and the Instance graph. Under the position of physicality, there is a layer which presents individual spatial position. Indicating individual entities' spatial region and position, the movement and collision is identified. These identifications of physicality become clues or precondition of events. Meanwhile, the agent's conceptuality and the reality will change by the result of agent's action according to how the agent receives the changes of entities in the physicality.

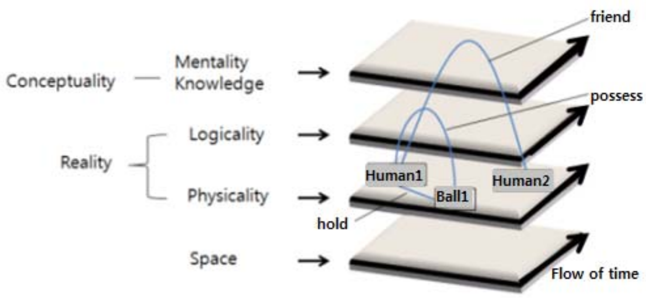

Fig. 2 The structure of S-T graph

S-T graph needs a representation corresponding to dual purpose. First, a representation that positions instances and events in order to create a perceivable and inhabitable virtual world for agents. Second, a representation corresponding to the process which agents perceive the virtual world and make it its own knowledge.

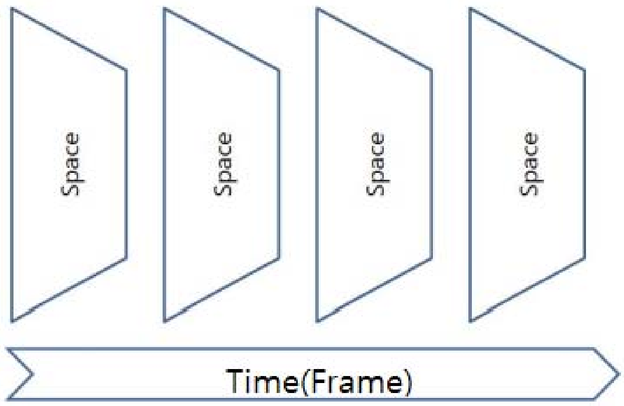

Fig. 3 space arrangement along with the flow of time

S-T graph presents situational changes through the existence and state of entities and relations. In order to indicate this presentation, it is important to show changes of individual objects and relations along with the flow of time. As you can see, the time and spatial axis are presented in the manner of orthogonal. The spatial changes are shown after arranging the snapshots of virtual world by the flow of time.

IV. Implementation

The implementation of the S-T graph system shown below in Fig. 4. In the main screen, user can identify all the system by diverse perspectives through the 4-parts. The screen shows a scene from the robbery story. The top-most view (1), called 'Ontology viewer', represents ontological hierarchy and its current action for involved objects. There is 3-layer view, marked (2), which include conceptuality, logicality and physicality. S-T viewer, marked (3), shows spatial positions and regions and mini-map for entire world at a current frame. S-T viewer functions instance creating, modifying, deleting and camera movements. The 3-layer shows all the instances and their relations by the perspectives of 3-layer. For example, ‘ human1’ is currently related with logical entity ‘hold’ and he has ‘diamond1’ in the scene so,’ human1’ instance link to ‘hold’(logicality) and ‘diamond1’ also link to ‘hold’ and the ontology viewer marked as (1) shows all the links to his properties and relevant class hierarchy at the same time.

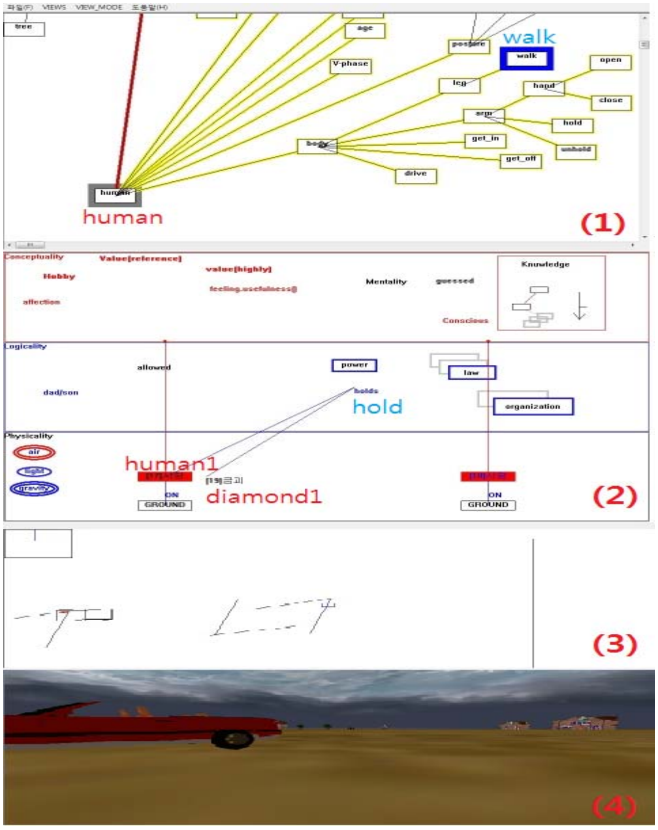

Fig. 4 The main screen of S-T graph system

The reality view, marked (4), shows current scene by the perspective of human sight using OPENGL library and it supports a special camera for observation with the movement by switching ‘observe-mode’. This is all about main-screen of S-T graph. Next, we are going to introduce how to create action and manage the time with frame editor. The frame editor is shown below in Fig. 5.

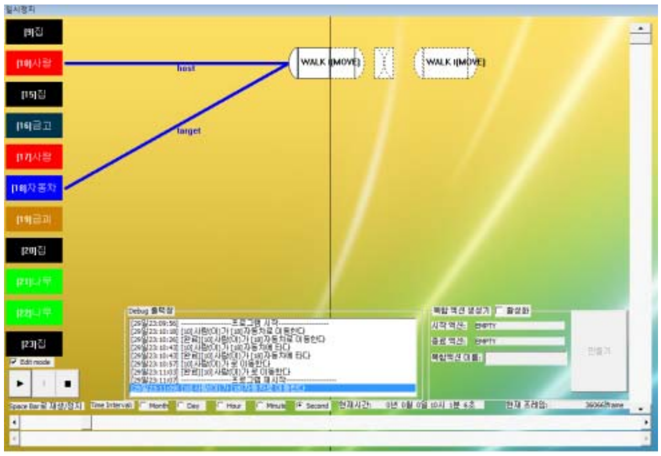

Fig. 5 The representation of situation on the frame viewer

Frame viewer manage actions and time(or frame). The Fig. 5 shows the situation that ’human1’ instance is moving to somewhere with the ‘car10’ instance and ‘human1’ is the host of this action. The meaning of a vertical line in the center of screen is current time. Enabling the time, actions will move to left and it will finish as the action totally move away from the current time line. The dotted actions show that they have not bound yet. Actions could be composite actions by users editing. For example, action ‘a’ and ‘b’ are bounded in the order of time and then, user clicked both actions and rename it to ‘AAA’ so, finally the ‘AAA’ is created which has both action ‘a’ and ‘b’. By using these composite actions, some primitive action can be different types of composite actions and composite action itself also can be the other composite action’s child.

Lastly, Fig. 6 shows how a robbery story is generated by S-T graph and frame viewer. The scene no.1’ human1’ is going out and ‘human2’ is watching it. And then, ‘human1’ moved to ‘car10’ and is getting in the ‘car10’ in the scene no.2. The Scene no. 3 shows ‘human1’ moved away from his house. And then, ‘human2’ went into ‘human1’’s house and held ‘human1’’s ‘diamond1’ after opening the ‘safe1’. Finally, ‘human2’ came back to his house and put the ‘diamond’ into his ‘safe2’. The whole story will be saved for a replay. The mechanism of the replay is not a rerun of all saved coordinates but uses actions in the array of action-list data. All instances have its own action-list and execute its actions according to the global time(frame) events in order to be synchronized with the other’s actions. Although this story looks a short story, there are many actions to be created for natural direction. So the actions are needed to be reused for the diverse situations. The scene no.6 shown in Fig. 6 bottom-right side shows that all the actions occurred in the robbery story is composed to the composite action ‘robbery’ and it could also be reused after filtering the actions by the agent’s decisions and learning.

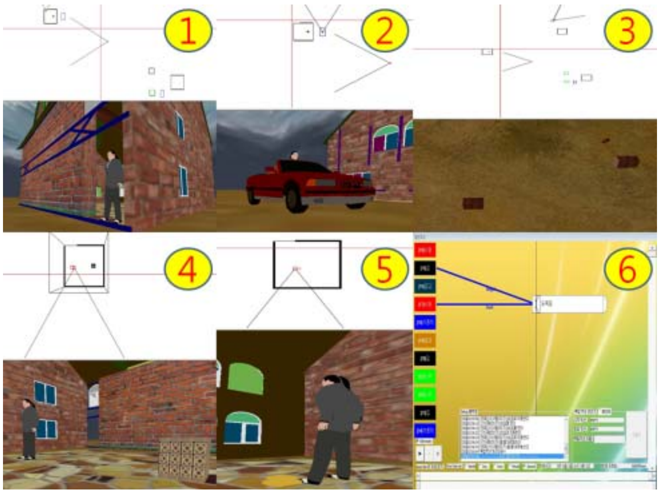

Fig. 6 A scenario of robbery

ACKNOWLEDGMENT

This paper introduces the implementation of S-T graph based on the ontology in the virtual world. The unexpected situations in the reality are created by interactions between object's properties and its events. The S-T graph first defines a scenario and creates composite actions for details using primitive actions. The more data defined in the ontology with its actions, the more immersions users experience with complexities. The implementation this paper aims to needs to have the process of perception, learning, cognition with its all algorithms to be stored into the knowledge base. The S-T graph also needs actions which handle the perception and cognition. The cognitive actions will be preconditions of events and the results of the events are also preconditions as well. Users only arrange the events to observe the changing process in the scenario. The scenario doesn't have to be a fixed but, it could be changed by user's purposes. If users want to feel they are in the virtual world, they can create agents for first-person perspective and operate them. The final form of the S-T graph will be a language learning system. The essential elements of actions will be defined as vocabularies which has unique meanings. The processes of making sentences from the scenario support users to get all the sentences what they've done by their operations to their agents. These processes are similar to the situation of language learning. Language education system is two-way system and will be the final goal of our project which gives users lifelike environments surrounding them.

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