시공간 속에서 일어나는 자유 재량적 사건의 논리적 시뮬레이션 플랫폼

(Logical Simulation Platform of Discretionary Events in Spatio-Temporal Context)

김 일 곤 † 박 종 희 ††
(Il Kon Kim) (Jong. H. Park)

요 약 다양한 사건들의 무대로서의 시공간 상황의 구축을 위한 정통적 시뮬레이션 기반을 개발한다. 사이버 세계의 정통성, 다시 말해 실제에 대한 논리적 충실성은 그 세계에서 일어나는 사건들의 다양성과 예측 불가성을 최대화함으로써 실현한다. 시공간에서 일어나는 사건의 시뮬레이션을 위한 지식 컴포넌트는 환경 요인, 객체, 사건, 상관관계가 있다. 자유 재량적 사건의 정통 시뮬레이션을 실현하기 위해 사건 활성화, 실행 방법과 사건 인지 함수들을 고안하였다. 본 시뮬레이션 환경에서 자주적인 에이전트들은 독자적인 존재와, 사건의 실행과 분리된 계획을 하는 능력을 가지고 있다. 사람의 의도를 반영할 수 있는 자유 재량적 사건의 정통 시뮬레이션과 관련 있는 기본적인 구성 요소들을 확인하였다. 시뮬레이션 방법의 실행 가능성을 보이기 위해 핵심적인 기술들을 중심으로 구현의 예를 보인다.
키워드 : 정통적 시뮬레이션, 지식 컴포넌트, 사건 활성화, 사건 인지 함수, 자주적 에이전트

Abstract An authentic simulation platform for events situated in spatio-temporal space is presented. The authenticity, i.e., logical fidelity to the reality, of this cyberspace is realized by maximizing the diversity and unpredictability of events occurring therein. The knowledge components and associated schemes required for the simulation of events situated in spatio-temporal space encompass the environmental factors, the objects, the events, and their interrelations. We devised event activation, triggering mechanism, and cognitive function related to event to realize an authentic simulation of discretionary events. The agents in this simulation environments are autonomous in that they have their own existence and capability of event planning. We focused on identifying basic constructs relevant to authentic simulation of discretionary events whose initiation depends on human intention. Several key ideas are implemented in a typical spatio-temporal situation to demonstrate the viability of our simulation mechanism.
Key Word : Authentic Simulation, Konwledge Component, Event Activation, Event Cognitive Function, Autonomous Agent

1. Introduction

It has long been a known fact that learning through experience is the most effective learning paradigm[1]. This fact is more evident in learning declarative subjects such as language or history[2]. The foremost premise for an effective education of declarative knowledge is the existence of diverse situations which the learners can be exposed to. Truly, such diversity is useful for any type of learning system as long as the principle of situated cognition is a valid proposition[3]. Computer-based tutoring systems have accordingly been evolving toward immersive types as their ultimate forms[4-5]. Central to these ultimate forms of intelligent tutoring systems is the capability of providing simulated real-life situations, where the learners

† 종신회원 : 경북대학교 컴퓨터과학과 교수
ikkim@knu.ac.kr
†† 비 회 원 : 경북대학교 전자전기공학부 교수
jhpark@ee.knu.ac.kr
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can learn by 'dwelling' in situations[4, 6].

In existing situated learning systems an environment has been a passive background rather than an interactive context[4]. Also, they allow an event to unfold along fixed flows only[7] rather than desirable unplanned paths. Moreover, they are concerned only with lexical concepts with no consideration of various factors relevant to simulation of 'real' situations[8]. These bottlenecks together spawn a number of specific drawbacks such as confinement in diversity of situations where the learners' immersion can take place[9] or restrictive modes of interactions[4]. Notice these bottlenecks are an inevitable consequence due to a lack of genuine intelligence and fundamental principles assimilated in the simulation. The ultimate solution to overcome these limits altogether is obviously to establish an *authentic* cyberspace. By an authentic cyberspace, we mean a simulated microcosm that is dictated by various rules and principles in a systematic and organic manner. While the visual effects of such simulation are finding their practical applications[10-11], the development of its logical aspects remains largely in its infancy[3-4]. Specific examples of the logical aspects are the natural laws governing physical phenomena and principles in social activities.

We aim to develop a simulation platform for an authentic cyberspace for situated learning. The rationale behind this authentic simulation can be reified only by a coherent cross product between millions of autonomous objects and numberless factors of responsive environment. Such a cross product would lead to generation of a myriad of natural situations in an unpredictable fashion in contrast to retrieval of prestored episodic situations.

2. Related work

There have been few works with a comparable objective vis-a-vis our work in that we aim to develop a general, comprehensive framework for simulating situations. To develop this overall simulation framework we need to address various issues ranging from object modeling to space construction to visualization. Most existing works deal with only part of those issues.

Script[7] is a knowledge model to express a stereotyped sequence of events in a particular context. It is aimed to represent procedural knowledge, i.e., event, in a declarative manner. Thus it supports only fixed flows of procedure. Inherently, Script is useful only for stereotypical events, but not for unexpected events. Script allows an event to be in terms of its relevant objects and conditions besides its flow. However, it focuses on the lexical aspects.

Specifically for language learning, one attempt to provide an immersive learning environment is made by an MIT group[4]. This work constructed a first multimedia learning environment. It offers two modalities of exploration of the environment to give the students a genuine feeling of 'dwelling'. However such feeling is not quite successfully generated because it is too constricting and uninvolving as admitted by the authors even with some supplementary measures. These limits are rooted obviously in the limited flexibility of 'canned' set of still image clips.

Another general language learning environment is Dustin[6]. It claims 'realism' in simulated environment, i.e., simulated agents look, talk, behave and react like real ones. This environment is equipped with interactive measures to handle user's feed back. It is obvious, however, that it also is based essentially on fixed flows of situation in spite of some degree of variations via branched flows.

VET[5] learning system provides a 3D learning environment. In a sense, its claim of immersive learning is more justified than previous systems in that various sensors are used to monitor the student's action and the associated data are used to control behavior of the virtual world. Also the tutor inhabits the virtual world together with other virtual objects. Further, it is noticeable that the causal links in its procedural knowledge are an important source of power to solve problems. As a multimedia learning environment, however, its main objective is to present procedures related with a task to be learned. VET is not designed to generate diverse situations in unplanned manners.

The proposed learning platform is aimed to generate maximally diverse situations in a coherent fashion.

3. Knowledge components of events situated in spatio-temporal context

3.1 Environmental factors

A space has its own environment in which situations might reside. An environment is defined in the proposed cyber-world as the common set of factors possibly affecting all of its residing objects and events.

Time : The time is the most prevalent factor applied to any object or event in any situation. While the actual instances of an event proceeds along the real time, its conceptual versions are stored to arbitrary logical time units in human knowledge.

Space : A physical object allows other smaller objects to reside in its space. This factor of space first provides a spatial stage for events and objects, and further lays a basis for other environmental factors.

Space hierarchy : A spatial environment is made up of many tiers of spaces from the universal space to a regional space down to an individual object's internal space. Many subordinate spaces are embraced by their common superordinate space.

3.2 Concepts

The concepts encompass the physical objects and logical concepts. An agent is a special type of object that has reasoning capability. The individual concepts and their interrelations have their "a priori" existence to any situation or event.

Individual concepts including objects : An event usually involves a number of objects, whereas an object could in turn be associated with many events. The objects are designed to exist independently of those events they might be involved in. Those pieces of knowledge associated with individual objects will be organized with the backbone of the object hierarchy. The spatio-temporal aspects of a situation as the basis of its residing events will be abstracted into concepts in declarative forms. This abstraction will be based on such rudimentary concepts as analogy, relativity and conceptualization of the situations[8]. It is often conceptually natural to treat an iterative event cycle as a whole as one single event.

Structural relations among concepts : A variety of relations are accommodated in addition to those usual structural relations such as meronymy and hyponymy[14]. One important category of such relations is the spatial relations in a composite object such as topology among its components, their connection types, e.g., component A is in component B, and their detailed relative positions.

Phenomenon : A phenomenon can arise either within an object, e.g., explosion of a bomb, or between objects, e.g., collision between objects. The phenomenon is characterized by its environment, preconditions, effects and development. Phenomena prevalent over a region would be regarded as part of the environment of the region.

3.3 Events

An event is a spatio-temporal occurrence that involves one or more objects and their actions that are organized in a coherent manner to produce a common effect. The event is characterized by, among others, its components such as the environment, its participating objects including the agents, and its procedure.

Discretionary event : We distinguish the discretionary event from the natural (or inevitable) event. For a discretionary event, a planning phase, however brief it may be, always precedes its corresponding execution phase. Of course there is a possibility this execution phase might be aborted halfway. An inevitable event such as a natural disaster, on the other hand, will proceed according to its inherent course, so no planning can intervene. Thus, the flow of a natural event is dictated only by its associated causality. That is, a natural event will start if only its preconditions are all satisfied and it is triggered.

Conditions in event : An event depends on many categories of conditions, which all are functions of such factors as the environment, the existence and states of objects, and the relations among objects. The triggering condition, one of those categories, has a role to ignite its associated event according to a need or wish of an agent. It is distinct from the other categories in its timing of application and instantaneous duration of validity.

Event flow: Stereotypical flow of event has been modeled in frame-based structures[7]. Beyond those monotonic flows we elaborate the event flow with several nonmonotonic types of flow. Specifically, an event may unfold along conditional or iterative flows in addition to a monotonous backbone flow[8]. Also an event flow may be interrupted and suspended until an interrupting event has run its course. Further, an event flow may be derailed from its original course due to a change in its surrounding environment or occurrences of other external events. A similar derailment might be caused also by some extreme states of its involved objects.

3.4 Situated events and objects

A situated event or physical object occupies at least a time and space extent. A spatio-temporal context of objects and events as situated in the global space is illustrated in Fig. 1(b). The current cursor designates the (temporal) present of the space. The area above the cursor corresponds to the history embracing all the historic objects and events. The shaded area denotes the future, and dotted lines indicate objects or events expected to exist or occur in the future. These prospective objects and events are estimated or scheduled based on their typical natures. Specifically, O_i denotes objects; H_i denotes habitats and their associated time extents; OM_i denotes mobile objects; E_i denotes events. A path of a mobile object is sketched in Fig. 1(c). A breakpoint indicates a time of stimulus causing a change to the path. The events could be classified temporally into the historical and periodic types. The historical type refers to one that happens only once or sporadically and may be endowed with its own historical identity. The periodic type refers to routine events, i.e., ones that recur periodically. Their periods range from daily to yearly to longer periods. As illustrated in Fig. 1(d), those conditions that routine events would be timed on will be formulated in terms of such periodic functions as sinusoidal or modulo functions. The occurrence of ro.utine event 'commute', for example, could be a sine function of 'brightness' and other factors.

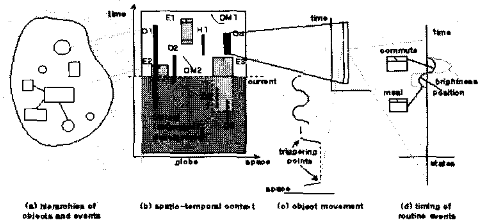

Fig. 1 Spatio-temporal context for objects and events

3.5 Actions

There usually occur a number of actions by animate objects in an event. An action is a sequence of movements and collectively produces some effects. The purpose of taking an action is in pursuit of its effects. A composite action consists of primitive actions and, possibly other composite actions. When an action of an agent affects the environment or other objects, or vice versa, the action becomes a key clue to steer its associated event the agent is involved in. In this light we will consider the action mainly with respect to its adaptation to the environment and neighboring objects. Specifically, its actual movements will be adapted, often dynamically, to the changing state of its environment. That is, its concrete aspects are adjusted after each movement, whereas its abstract aspects are planned only once ahead of its execution.

4. Activation and triggering of discretionary event

4.1 Activation

A planning phase precedes its corresponding execution phase in a discretionary event. The planning is worked out based on typical or expected values of conditional parameters as acquired from experience and its statistical analysis. Meanwhile, the execution phase is based on actual values. These actual values may well be different from those typical or expected ones. In an execution phase, an agent is endowed with innate capabilities to perceive and recognize the states as they are, of its surrounding situation, i.e., the environment and neighboring objects. That is, an agent is designed to be able to see, hear, and feel.

Planning phase : We illustrate the event planning with 'go' as an example. Out of its numerous lexical meanings the one we chose to realize here is movement from a reference location to another location. The event of go() employs several different kinds of action move(), e.g., walk(), according to the moving distance. To describe notations to be used below, $A(t)$ denotes an actual value; $A_i(t)$ an actual value as known to *agent i* where $A_i(t)=A(t)$ or $A_i(t)\neq A(t)$; $\underline{A_i}(t)$ a typical value as statistically obtained by *agent i*; $A_i(t)$ *when* $t>t_0$ (the current time) a valuc estimated by *agent i*. The road system is modelled in a road graph for its connectivity, and additional data structures for its other spatial relations as described earlier. The major elements of a planned event denoted by bold face are its environment, agents, objects, preconditions, flow, and effects. Its triggering conditions will be described in separation later.

All those input parameters are of typical or estimate values as stored in an agent's KB. Each iteration above would generate as its result a tuple of three parameters, i.e., (start location, end location, traffic means). Based on this result their relevant states would be updated to reflect changes in their estimated values. The direction and distance of each path segment could be derived from the first two parameters. The corresponding energy, time and fund states of its agent would then be updated according to the third parameter. For example *agent.energy(t)* $\in S_0(t,s)$. A reiteration would ensue if an updated value is judged to be out of their limits. A final result of GO-Plan might be formulated like,

$\Sigma_{i-1..N}(\overrightarrow{(agent_0.s\rightarrow location_s, agent_0.s\rightarrow location_e)}, move_i())$ where $move_i()$ denotes the move type with its domain of *{walk(), bike(), ...,}. When i=1,* $agent_0.s\text{->}location_s$ = $agent_0.s\text{->}current$, and when $i=N$ $agent_0.s\text{->}location_e$ = $agent_0.s\text{->}Destination$. This abstract path is modelled into a directed graph, i.e., $G=(V, E)$ where V denotes a junction set and E denotes a segment set with the move type as a weight.

Execution phase: In execution, the space and time are treated as variable factors for movable objects, whereas the space is set constant for immovable objects. Notice the time is variable for the object itself and reflected in its existence. Further, there could be numerous causalities among the states. A state of low visibility and wet surface, for example, could be associated with a rainy weather. These invariable associations should be stored in terms of rules in the KBs. Some initial states such as a severe weather could cancel its execution. However, this possibility cannot be reflected on any internal condition in, but an external condition for starting its associated execution, e.g., GO-Execute. Such a condition needs to be specified with an appropriate violation measure, which will not be given below. Notice the execution phase is structurally augmented from its planned phase by its initial states.

An agent's decisions in execution phase may be made in her partial scope over the situation that changes as it proceeds, whereas the planning is performed in her overall scope over her P-KB. There are often cases where states in an event become clear only gradually as its execution unfolds because of its agent's limited scope or perceptional capability. The initial states are specified with their actual values from a situation. The difference of an actual state from its typical one, for example, an unseasonably warm winter in GO-Execute(), presents several issues such as possibility to bring about additional events[16]. In evaluating the states, its subjects, i.e., agents, are given the highest priority in deciding its reference point. The next highest priorities are given to the environment, agents, objects, and preconditions, in this order.

Each instance per se of event will be recorded in its agent's memory. An evaluation of its results also may follow depending on its agent's character and the nature of the situation the event occurred in. This raw history or evaluation might be traced as necessary, for example, when subsequently triggering a similar event. The evaluation is performed in a vertical manner, i.e., on each individual event in the direction from the its overall down to its subevents, or in a horizontal manner, i.e., on many instances of the same event. The latter evaluation would produce statistical results, often forming typical values. Consider an instance set of event E_k, i.e., $I_k=\{I_i^k,\ i=0,1,2,..\}$, $E_k=f_k(v^k{}_1,v^k{}_2,\cdots)$ and $E_k=<\cdots E_l,E_{l\cdot 1}\cdots>$. A vertical evaluation would use a function like $v^k{}_j=f_v^j(v^l{}_n,v^l{}_{n\text{-}1},\cdots)$, and a horizontal evaluation one like $f_h(I^k{}_1,I^k{}_2,\cdots)$.

4.2 Triggering mechanism

Some state or action can be a catalyst to inspire a certain need in an agent, which in turn could lead to a search for an event with the need as its effect. In a discretionary event of 'vacation', for example, such a catalyst might be reading calenda, feeling fatigue, or hearing about vacation. When a state $O_n.s_i$ is perceived by an agent, its reciprocal state $s_k=\overline{s_i}$ would be reasoned via $O_i.s_j\mathcal{R}_rO_i.s_k$. Given a need corresponding to s_k a search would be performed for an event such that $O_n.s_i\subseteq E_i.\{f_i\}$ for each $E_i\in E$. If a proper event is found in the search, its associated factors could be added to its triggering condition set in addition to the original need. As a result, a set of triggering conditions is made up of an original set and a derived set of conditions, i.e., $C_t = C^o{}_t \cup C^d{}_t$. To implement the triggering mechanism, an agent will have, in its P-KB, a need list, $\{N_i$: N_i = *the i-th need*$\}$, and a wish list $\{W_i$: W_i = *the i-th wish*$\}$. Also, its required functions include Perceive(cond), Traverse(P-KB, cond), and Inference(P-KB, cond), where *cond* = {a triggering or other condition}.

Overall procedure : The overall procedure of event instance proceeds basically in the following order as illustrated in Fig. 2(a): (1) there exist a set of objects emitting their sensory signals (or symbols), (2) the agent perceives those signals and stores their associated attribute values, (3) the agent recognizes the contents of those values, i.e., their associated state, (4) the agent may find a need to resolve the recognized state, (5) the agent searches for an event with the found need as its effect, (6) the agent decides the timing of its actual activation. The states in a condition include physically observable types, e.g., road state and body temperature, or conceptual types, e.g., time and tension. The former types are evaluated as perceived, but the latter types are first converted into observable states often with a help of artifacts. The sensory signals must be perceivable audibly or visually with the agent's sensory capabilities. Such signals may be symbol ones. Their values can be changed by their associated objects' internal processes or external impacts. Further, some change on a state could propagate to other states via their causality, causing further changes.

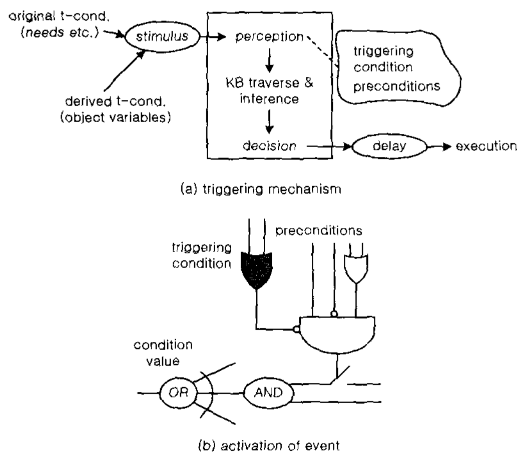

Fig 2 Activation of discretionary event

Implementation model: The sole role of a triggering condition is to ignite its associated event.

so its effect needs to exist only at its start. A triggering condition could be modelled as an enable for a switch controlled by a set of preconditions as illustrated in Fig. 2(b). The actual timing of an event being started does not always match that of its preconditions and triggering conditions being satisfied. Either timing can precede the other one depending on the event type[16]. The other conditions in an event are designed to apply through its course if their values may change along the event. That is, all the conditional variables except for the triggering conditions are supposed to remain applicable throughout the course of event.

Modes of relations between triggering and activation : There can be two modes of connection from its triggering to its activation for a discretionary event. In one mode the agent first selects a time to activate the triggered event regardless of the states of its preconditions. Then, each unsatisfied precondition, if any, would be considered in the planning phase with a purpose of its satisfaction. Given an event $E_0=(Env, ..., C_p, ...)$ *where* $C_p=\{C_1(t), C_2(t), ..., C_n(t)\}$ and a set of unsatisfied conditions $C_u=\{C_i, i=1,2...N\}$ *such that* $C_u \subseteq C_p$ *and* $C_i(t_a) \neq true$ *for any i where* t_a *denotes the activation time*. For each $C_i(t)$, a search is to be conducted for such a sequence of events that their execution would lead to $C_i(t_a)=true$. Even for this headlong activation, however, all its essential preconditions are to be met as its minimum premise. Its agent's existence is an example of essential precondition[16]. In the other mode the agent will attempt to estimate the earliest time that all the conditions would be satisfied, i.e., $C_1(t) \cdot C_2(t) \cdot ... \cdot C_n(t) = true$. A search for such a time could be part of an event planning. In case there exists any unsatisfied condition, a derived event may need to be performed. This process could produce new unsatisfied conditions recursively. Specifically, to satisfy each such condition, i.e., $C_i(t) \in C_u$, a proper event E_c would be instantiated at time t such that $t_t<t<t_a$, where $t_t=$ *the triggering time of* E_0. In general, $t_a = t_t + \Delta t$. A time delay Δt includes an inferencing time for event planning at its minimum, plus indefinite times depending on its agent's characters. In a natural event, if $C_1(t) \cdot C_2(t) \cdot ... \cdot C_n(t) = true$, *then* $t_a=t_t$ *else* $t_a = NULL$, i.e., misfired.

4.3 Cognitive function related to event

If an event is triggered, its instances stored in the P-KB are traced besides its preconditions. This tracing is preceded by an cerebral alignment of personal history on that event along the time dimension. Those parts of knowledge identified as relevant in tracing are alerted as highlighted in Fig. 3. These alerted parts are evaluated for its present instance and prepared to be retraced on its subsequent instances. This tracing creates an effect of extending triggering condition set.

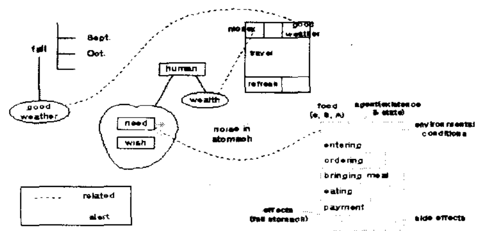

Fig 3 Part of P-KB relevant to 'hungry' state

5. Implementation and discussion

5.1 Implementation

We implement the proposed ideas and techniques as developed so far to simulate the cyber world with various events. In light of the sheer extent of its scope, this implementation is never intended to be complete. The implementation in Visual C++ 6.0 and MFC based on MS Windows. We chose hiking in a mountain as a situation where various events might occur.

Fig. 4 shows the agent's reaction when the stream is found of wadable depth. She continues along the originally planned path without needing to search for another path. That is, she only modifies the transfer mode from walk to wade for this leg of path in the planning phase. If she has decided to bypass she needs another planning phase for a new path to bypass it. She would also updates her abstract map according to her finding around the stream.

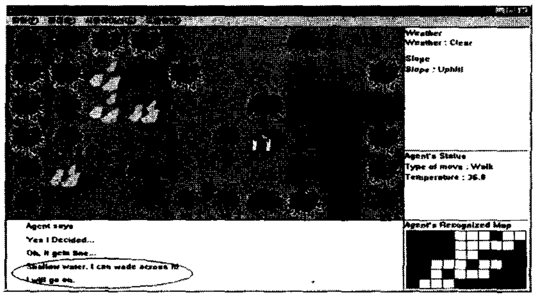

Fig 4 Agent's reaction when the stream is found of wadable depth

5.2 Discussion

We have implemented only several key schemes of our simulation mechanism to demonstrate the potential diversity of situations unfolding in a systematic manner. Firstly, the objects constituting a situation are designed to behave as autonomous objects. Since an autonomous object exists on its own, her internal states would proceed without reference to particular situations. These internal states are combined with the external states to account for numerous events we might face in a situation. An agent as an important object type could be any other human object. With such a replacement in a situation, some internal event, e.g., stomach upset, could happen at another time or even not happen altogether. Secondly, her knowledge on an event and the associated decision should be different from those of the originally cast human. Facing the flooded trail the decision an agent chooses among alternatives, e.g, jump over, wade, bypass, or give up, was designed to vary depending on her states or propensity.

Thirdly, by separating the agent's notion and the reality on a situation their possible discrepancies were highlighted as another typical event source. Fourthly, a new event associated with the precondition needs to be executed prior to any further progress of the current event in case any of its essential preconditions is not satisfied. In this regard, we showed two cases of interruption of the current event, and alternate use of planning and execution phases. The agent's knowledge has been modified accordingly on finding discrepancy in the path, so became able to directly take the right path. These key schemes have been collectively exploited in the implementation to maximize the diversity and, consequently, naturalness of events' unfolding in a situation.

6. Conclusion

We have identified the knowledge components and associated schemes required for the simulation of events situated in spatio-temporal space. Those knowledge components encompass the environmental factors, the objects, the events, and their interrelations. We devised several key schemes to realize an authentic simulation of situated events and objects. We first elaborated on the time and space elements of environment where diverse events might take place. The agents in such environments are autonomous in that they have their own existence and capability of event planning. We focused on identifying basic constructs relevant to authentic simulation of discretionary events whose initiation depends on human intention. These knowledge components and associated schemes collectively lay a groundwork for providing an authentic spatio-temporal context, which are rarely seen in conventional simulation mechanisms. Specifically, they allow numerous real life situations to unfold naturally as a coherent platform for a wide variety of applications, notably, situated learning. We demonstrated the feasibility of those knowledge components and key schemes by applying them to a typical situation.

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김 일 곤

1991년 서울대학교 전산과학과 박사학위 취득, 1992년 ~ 현재 경북대학교 컴퓨터과학과 부교수로 근무, 1997년 3월부터 1998년 8월까지 미국 죠지타운대학교 병원 ISIS 연구소 방문연구자, 관심분야는 지능형 에이전트 시스템, 분산시스템, 의료정보학

박 종 희

He acquired his Ph.D in Computer Eng. from Univ. of Florida in 1990. He has since been on the faculty at Kyungpook Nat'l Univ. in Korea. His research interests focuses on intelligent systems simulated in spatio-temporal settings. The specific research topics encompass intelligent tutoring systems, futuristic games, simulation of cyber world, and computer based diagnosis