Communication through Virtual Active Objects Overlaid onto the Real World

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ABSTRACT
A SpaceTag is a virtual object that can be accessed only from limited locations and time period. Users of the SpaceTag System can see and create SpaceTags using a portable terminal with a location sensor. We have categorized it as an *overlaid virtual system*, in which virtual objects are overlaid onto the real world based on time and space coordinates. This architecture is more promising, general purpose, low-cost, and more realistic than other location-aware system architectures like augmented reality that attaches virtual information onto real objects. The SpaceTag System can be offered as a public information service that is a common platform for gaming, advertising, city guide information, etc. We have already implemented a prototype.

In this paper, *active SpaceTags* are additionally proposed. They are enabled to interact autonomously with human and other SpaceTags, realizing new applications of interactive games, virtual creatures (SpacePet), etc. The computation model of active SpaceTag is described here. This paper also gives a discussion by regarding the SpaceTag System as a CVE. It is a considered as special CVE that has a same space/time coordinates as the real world. SpaceTags and SpacePets can be regarded as objects and active objects in the virtual space, but they are projected onto the real world. Users can communicate with each other through these objects. This paper also describes how such communication occurs.

Keywords
Overlaid Virtual Systems, Virtual Pets, Mobile Systems, Augmented Reality, Autonomous Agents, Community Computing, CVE Architecture.

1. INTRODUCTION
The SpaceTag System [10,11] supports virtual objects, called SpaceTags, overlaid onto the real space. Figure 1 illustrates an intuitive image of SpaceTags. A SpaceTag is a virtual object with location attributes, which can be accessed only within limited locations (within the effective zone of the SpaceTag) and limited time period. Users can see SpaceTags with a handy terminal equipped with a location sensor and a communication device. They can even create a SpaceTag and stick it onto the space, which can be seen by other users.

We have proposed the basic idea in [10] and discussed public applications and social impacts of the SpaceTag System in [11]. Please note that we call each virtual object "a SpaceTag," and the total system "the SpaceTag System."

It can be regarded as a kind of augmented reality system, but we have categorized it as an *overlaid virtual system*. The most important nature of the SpaceTag System is its low cost. It can be deployed as a natural extension of current mobile systems with cellular phones and PDA tools.

In this paper, after introducing the concept, design, and advantages of the SpaceTag System in section 2, we will discuss an extension of the SpaceTag System to enable active SpaceTags

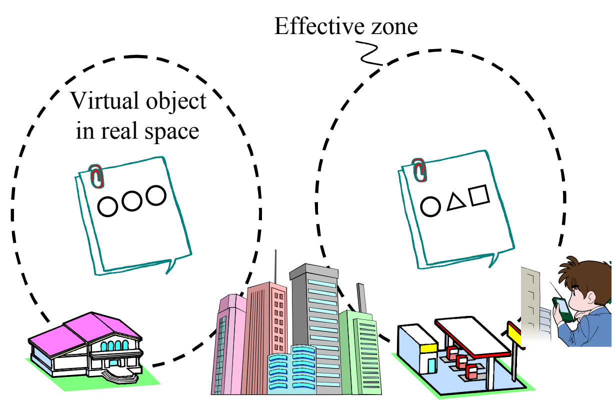

Figure 1. An Intuitive Image of SpaceTag

in section 3. An active SpaceTag is a SpaceTag that can autonomously move and interact with other SpaceTags and users. With this extension, many applications will be available, including virtual pets that we call SpacePets. Section 4 describes design and usage of SpacePets. The SpaceTag System can also be regarded as a CVE system overlaid onto the real world. We will also describe how people can communicate with each other using SpaceTags, active SpaceTags, and SpacePets in sections 2, 3, and 4, respectively. Section 5 will conclude this article.

2. THE SPACETAG SYSTEM

2.1 Concept

A SpaceTag is a virtual object that can be accessed *only* within limited area and limited time period. It sounds to be inconvenient and restricted, but it is the essential aspect of SpaceTag. Of course, in some applications, it will be more convenient if SpaceTags can be accessed remotely. However, our policy is to give convenience by other media such as WWW, as the SpaceTag System can be interfaced with other media.

2.2 Architecture

Figure 2 shows the basic design of the SpaceTag system. It basically consists of a server and clients. A user has a handy client terminal equipped with a location sensor and a communication unit.

2.2.1 Server

SpaceTags are stored in a database on a server machine, and they are broadcasted from the server to terminals (clients). A server is composed of a database subsystem and a communication subsystem. The server and the database are supposed to be managed by a SpaceTag service company.

The database is required to manage SpaceTag objects. A SpaceTag is a digital object that has at least the following attributes: *ID*, *data type*, *effective zone*, *effective time period*, *access rights*, *channel*, etc.

- ID is a serial number given by a server, which is not shown to users. Data types may be text, image, audio, downloadable computer program, URL, *ML (HTML, XML. SMIL, VRML, HDML, MML, …), etc.

- Effective zone means the area within which a user can open the SpaceTag. Detailed specification of the effective zone will be shown later.

- Channel is like that of TV broadcasting. For example, tourist channel, communication channel, or gaming channel can be given. If a user selects a channel on the terminal, only SpaceTags that have the same channel attribute are shown.

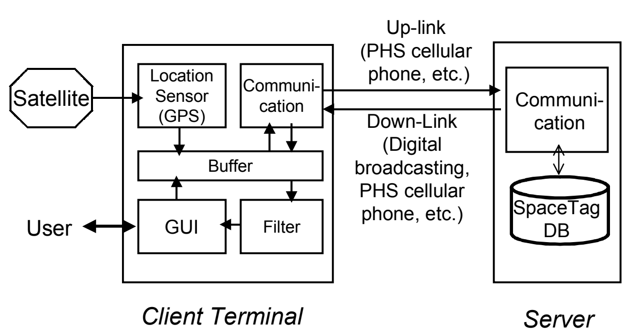

Figure 2. Configuration of the SpaceTag System

Since the objects have a uniform structure except the multimedia contents, the database can be implemented with a standard relational or object-relational database product. Almost all queries are retrievals of SpaceTags that can be accessed from a particular position and time. This fact gives possibilities to tune the database performance for queries.

There are two cases in creating and modifying SpaceTags.

- **By the service company:**
  In cases of tourist information and advertisements, etc., information provider (city government or advertising agents) commissions the service company to manage the SpaceTags. These SpaceTags can be modified or removed only by the service company.

- **By end-users:**
  A SpaceTag created by a user is transmitted to the server by the up-link communication and stored in the database as a SpaceTag with location attributes of the place where it was created. In this case the SpaceTag can be removed only by the creator or system administrators. Appropriate access right management should be applied.

It must be inhibited for users to access SpaceTags remotely. If it were allowed, remote access would become a popular behavior of users because remote access is simply convenient; the basic concept of SpaceTag might be crashed and some applications would become nonsense. If remote access is required, the service company can select remotely accessible SpaceTags and copy them to WWW, or the company can create SpaceTags whose contents are URLs indicating the open data. The SpaceTag system and WWW can be linked and cooperate in this way. It is also possible to give a wide effective zone to a SpaceTag.

It should also be inhibited for users to create SpaceTags remotely, in order to avoid SPAM-like SpaceTags. Only the service company should be allowed to create them remotely. For more detailed access right management, membership systems are considered [11].

2.2.2 Communication

The SpaceTag system uses two way communication: up-link (client to server) and down-link (server to client).

For the up-link communication, we have adopted a popular digital cellular phone system. Required bandwidth is not so wide, because what are transmitted from a client to the server are some control commands, position data, and SpaceTags created at the client terminal.

For the down-link communication we currently have two options: public digital broadcasting and micro-cell type cellular phone (Japanese PHS (Personal Handyphone System)).

In case of adopting digital broadcasting, surface broadcasting is more appropriate than satellite broadcasting, because broadcasting area is smaller. For example, if a 10 Mbps bandwidth channel is reserved, about 60,000 SpaceTags of 1 KB short text can be broadcasted per minute. If a large data like image is contained within a SpaceTag, it is possible to broadcast only indexing information to get the real contents from other network in an on-demand manner, e.g., from the Internet through http or other protocols.

If a micro-cell type cellular phone is adopted, the bandwidth is narrower. In case of Japanese PHS, 64 kbps can be reserved. However, each service area is small enough to reduce the number of SpaceTags to transmit in one area.

2.2.3 Client Terminals

As shown in Figure 2, a client terminal has the following functions.

(1) Location sensor:

It senses the position of the terminal itself. We have currently two options for the sensor, (Differential) GPS and PHS.

(2) Communication:

It implements the up-link and down-link communication functions. The manner of connection depends on its implementation. If digital broadcasting is adopted, it receives SpaceTags every time. If PHS is adopted, it should be connected continuously or periodically.

(3) Filter

This function selects SpaceTags that should be shown to the user from all received SpaceTags and stores them. The filtering is based on location, time, channel, keyword, or other attribute values. Location, time, and channel-based filtering functions are mandatory; others are optional. If a wide-area broadcasting is adopted as the down-link communication, many SpaceTags might be filtered out by this function, because most of them are not within the neighborhood. Selected SpaceTags are cached on the terminal as long as it can be accessed.

Some optional functions can be appended. Content-based filtering is one of them. Another example is notification service, which is to notify the user when a particular specified SpaceTag is detected.

It should be noted that the location-based filtering function could be removed to show SpaceTags that should not be accessed from outside of the effective zone. Currently we are assuming that this type of cheating does not occur. However, we should design more secure implementation against cheating. Developing one-chip SpaceTag terminal is an example of secure design.

(4) User Interface (UI):

It provides the following functions:

- List up all the SpaceTags that can be accessed.

- Creation of new SpaceTags; stylus pen interface, audio microphone, and digital camera (still, motion) are possible future interfaces to create SpaceTags. Currently any Windows files can be stuck as a SpaceTag, on our prototype system.

- Sticking newly created SpaceTags in the real space, and detaching or copying SpaceTags from the space. If a SpaceTag is detached and moved from the space to the terminal, a control command is sent to the server and the server removes the SpaceTag from the database, or decrements the number of the SpaceTag if it is defined as a multiplied one.

- Channel selection. A list of channels is shown, and the user can select one or more channels from the list. All SpaceTags that belong to the selected channels are shown.

2.3 Prototype

We have prototyped the first version of the SpaceTag System. For the communication, we have adopted the PHS for both up-link and down-link. The server is located in our laboratory; Oracle 8 is adopted for the database. Terminals are implemented on usual notebook PCs running Windows 98, with the SpaceTag client software, shown in Figures 3 and 4. In Figure 4, the user is shown as a face icon at the center of the map, where the user is standing at this moment. SpaceTags are shown as file-type icons or question mark icons. A SpaceTag shown as a file-type icon can be opened, but those shown as question mark icons cannot be opened, since they are not close enough. Farther SpaceTags are completely hidden. Effective zones of SpaceTags are shown as circles, which can be suppressed optionally.

By usual drag-and-drop operations from/to Windows folders or the desktop, SpaceTags can be detached from or stuck onto the real world.

In our trial use, we found that the error range of location was less than 10m, using the Differential GPS system. This is precise enough to offer many applications described later.

2.4 Future Perspective

In June 1999, half year after our first publication on the SpaceTag System, EPSON Corporation started to sell “Locatio” [13] in Japan. It is an integrated handy terminal that has GPS, LCD (3.9 inch), digital camera, and PHS. Its weight is 260-290 grams. Its

Figure 3. A Client Prototype

market price is under 100,000 yen, i.e., under US$910 (without PHS). For location sensors, it can use GPS and PHS complementarily.

Since its memory and disk space is not enough, currently it cannot be used for a SpaceTag client. However, this product suggests that it will be able to start the SpaceTag service in very near future.

Another good news is IMT-2000. It is the next standard of mobile phones, being discussed now. In near future, we will be able to enjoy high-speed (144Kbps-2Mbps) multimedia mobile communication with a global standard. SpaceTag will be a candidate of its application.

2.5 Applications

The SpaceTag System is intrinsically inefficient because accessibility is limited. Its application is mainly in the entertainment field, rather than the business field. In this subsection we give some applications we are expecting.

2.5.1 Public Information Service

SpaceTags can present location-dependent public information. Examples are information for tourists that describes and illustrates famous sightseeing points, public announcement to warn people against pickpockets, to show temporal traffic regulation, to show the place of an event, etc.

2.5.2 Multimedia Attraction

With SpaceTags, we can implement attractions and entertainment scenes at festivals or events, like fireworks. If a city offers many multimedia attractions with SpaceTags, many people will visit there to enjoy them.

2.5.3 Real World Adventure Game

SpaceTags can be used for items in adventure games like secret keys, hints for puzzles, instructions, etc. Players carrying terminals walk around in a city, getting and putting SpaceTags according to a game scenario. Players may meet other players like MUDs, but it is not a dungeon but a real city! This type of game is better for our health than existing game machines, and realizes multi-player games naturally.

2.5.4 Advertising Event

People must move to access attractive SpaceTags. It causes some economic impacts. For example, suppose that a supermarket chain store announces that some SpaceTags will appear at some of the chain stores on a particular day and people who get the SpaceTag will win a prize. This campaign will gather many customers at all chain stores.

2.5.5 Moving Advertisement

A SpaceTag can be shown as a moving object, by periodically changing its location parameter. Using a moving SpaceTag for advertisement, we can provide a moving advertisement. It is only displayed to small number of people, but sometimes more effective than common advertisement like banners on Web pages. It is because it gives strong impression and sometimes causes

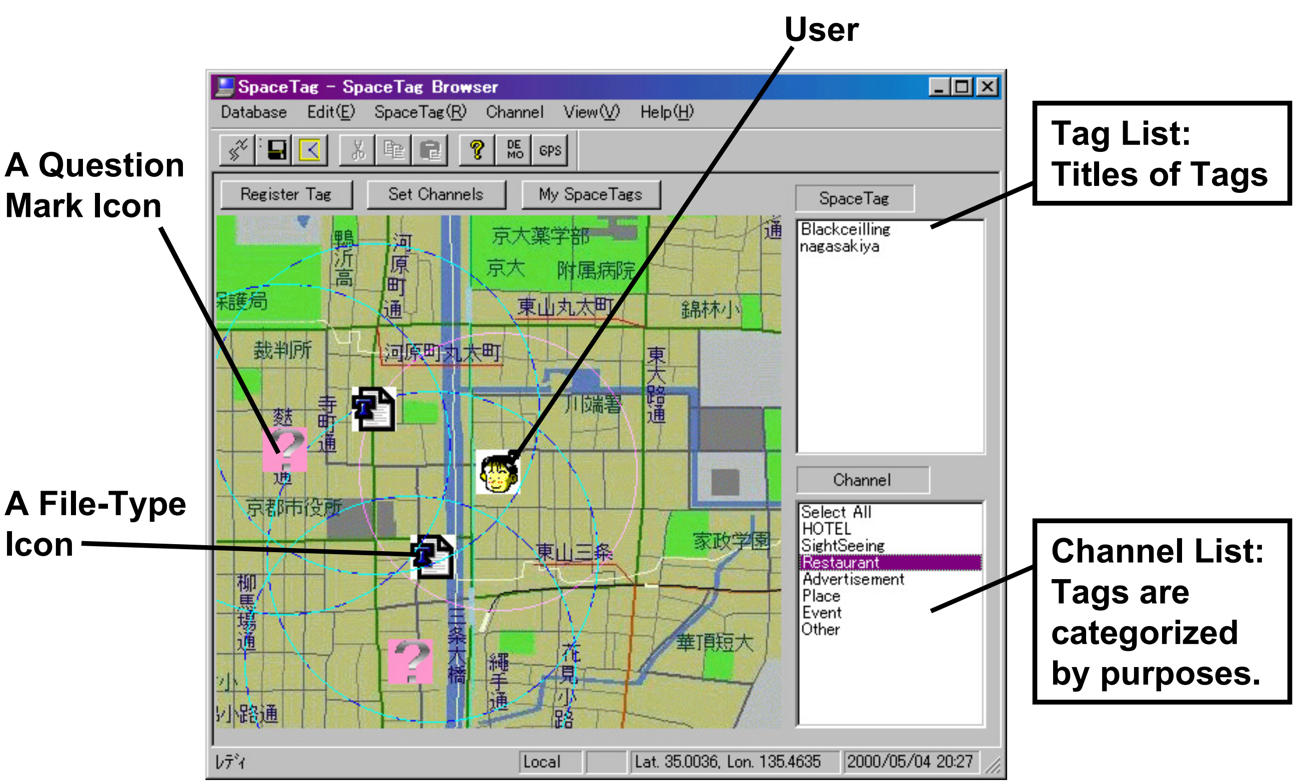

Figure 4. User Interface of Our Prototype

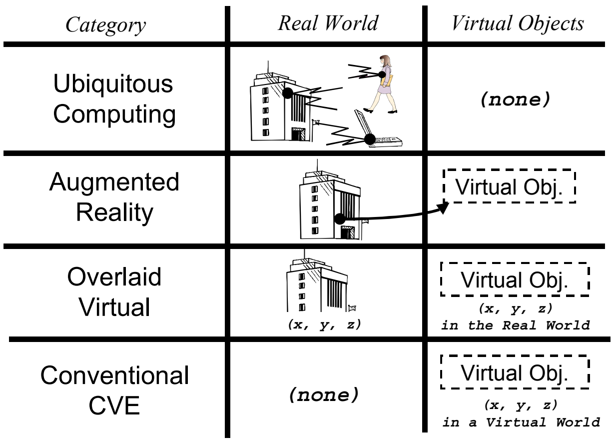

Figure 5. Location-aware Information Systems and Virtual Environments

rumors about the time and place to watch it.

2.6 Communication through SpaceTags

Besides applications shown above, the SpaceTag System can be used for human communication.

A SpaceTag put by a person is shown to unspecified people nearby. This means that a SpaceTag can be used for instant communication with people around the user. For example, SpaceTags like bills to ask for help to search a lost child, to offer a ticket exchange at event sites, and to look for partners to enjoy themselves.

2.7 Overlaid Virtual System

In this subsection, we try to describe the model of overlaid virtual system, comparing with other system models. Figure 5 categorizes location-aware information systems and virtual environments.

The first category is *ubiquitous computing*[1]. In this category, small electronic devices are attached to real objects. The device is enabled to communicate with each other in a wireless manner like radio waves or infrared. This type of device is also attached to portable computers or human users. They detect each other, sense surrounding situations, and give appropriate services according to the situation. Examples belonging to this category include Cyberguide [1] and Active Badge [12]. In this category, no virtual objects are basically provided. Services are given only in the real world.

The second category is *augmented reality*. This concept was originally invented in contrast to *virtual reality*. While virtual reality systems just create realistic 3D computer graphics and give interactive interfaces to the graphical objects, augmented reality is intended to give strong relationships between virtual objects and

[1] It may not be the correct definition of ubiquitous computing, but here we use this name to refer to this type of architecture since many ubiquitous computing systems take this architecture.

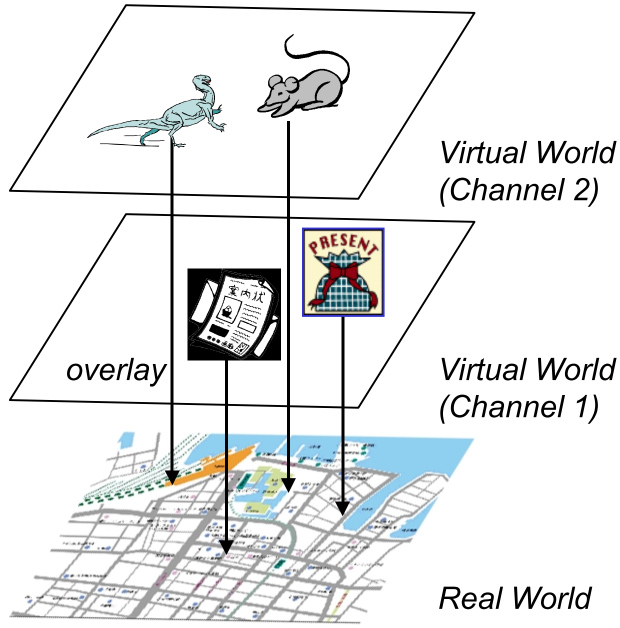

Figure 6. Overlaid Virtual System: Concept

real objects. Virtual objects are used to give information about real objects. Examples of typical augmented reality systems are NaviCam [7], UbiquitousLinks [2], and Augment-able Reality [8]. In their cases, special ID-tags are attached to real objects. The systems detect these tags and retrieve related information. Virtual Objects are basically given independently. They are not supposed to be in a virtual world that has time/space coordinates.

The third category, *overlaid virtual,* includes the SpaceTag System, Touring Machine [4][2] and Mixed Reality Systems [9]. On this architecture each virtual object has location attributes, where the object should be placed.

Overlaid virtual systems may be regarded as a subcategory of augmented reality, in the sense that virtual objects can give information of real objects. However, overlaid virtual systems can also be used without real objects, and its implementation is quite different from augmented reality systems. Hence we have given a new category.

As shown in Figure 6, virtual objects are not linked with real world objects, but they are just overlaid. A virtual object belongs to one of the multi-layered virtual worlds, like a game world, advertising world, hobby world, pet world, sightseeing world, city information world, etc. Each world corresponds to a channel, in case of the SpaceTag System.

Comparing with the first two categories, the most important benefit of the overlaid virtual architecture is that it is free from real object management. In case of the first two categories, small tags or devices must be attached to real objects. This fact causes

[2] In [4], they categorize Touring Machine as an augmented reality system, but we re-categorize it because it can be used without real objects.

the following four kinds of harmful costs proportional to the number of objects. Hence we do not think they are realistic implementation for large-scaled, public and open use.

- Hardware costs of devices or tags.
- Labor costs to attach them to real objects.
- Management costs of real objects. Without management, devices or tags might be removed or exchanged by people who are not familiar with the system. Object ID management and maintenance are also included within the management cost.
- Negotiation costs. Before attaching devices or tags, the system administrator should negotiate with the owner of the object.

Of course, augmented reality systems do not always use tags. Recognizing real objects by pattern recognition techniques is an example. In this case, however, real world object management is still necessary. System administrators should collect information about shape, color, and material of real objects.

One of the drawbacks of the overlaid virtual system is that it cannot attach information to moving objects. However, our standpoint is that lower cost is more important than this drawback.

Then, what is the difference between the SpaceTag system and Touring Machine or Mixed Reality Systems, which we also categorize as an overlaid virtual system? Touring Machine can be regarded as a research prototype to investigate the possibilities of user interfaces for overlaid virtual worlds. Its user interface is a heavy one using HMD, neglecting high cost and heavy weight. Mixed Reality Systems are also costly and have only in-house implementation, pursuing real 3D images and precise positioning. The SpaceTag System gives a basic architecture and application possibilities of overlaid virtual systems, supposing lightweight and low-cost devices. In future, CG and device technologies found in Touring Machine and Mixed Reality Systems will be improved and become able to be applied to the SpaceTag System.

2.8 Overlaid Virtual Systems as CVE

Finally, the last category refers to existing CVE systems like FreeWalk [6], MASSIVE [5], MUDs, and many multi-user computer games. In this category, virtual objects are given in the context of a virtual world, but the real world is not considered. Users must go into the virtual world using some user interface devices.

Overlaid virtual systems can be regarded as a CVE that has a strong location-based relationship to the real world. Users do not have to go into the virtual world, because the location itself is a part of user interface that gives correspondence between the real and virtual worlds. A user can enjoy a virtual environment, just by tuning his or her portable device to one SpaceTag channel, which corresponds to a virtual world.

In conventional CVEs, an important technical issue is how to support awareness information between users. In overlaid virtual systems, however, the support is not necessary because social communication cue in the real world is available. On the other hand, there are other problems: how to find other users who are in the same virtual world (i.e. enjoying a same channel), how to interface between a user and a virtual object with a small device, etc. Moreover, we have a physical constraint that only people who are close to each other in the real world can collaborate. With these reasons, we think it would be better to call it a Collaborative Semi-Virtual Environment.

3. ACTIVE SPACETAG

3.1 Design Goals

An *active SpaceTag* is a SpaceTag that can autonomously interact with other SpaceTags or users. This is a very important enhancement of our SpaceTag system.

One of the good natures of the SpaceTag System is that it will be enhanced in its bandwidth, its precision of location, or its interactive interfaces as the evolution of computer and communication technologies, *keeping backward compatibility with old SpaceTag Systems*. Like the design of Touring Machine, a SpaceTag client terminal may be equipped with an orientation sensor in the future, which will enable users to find out the direction in which a SpaceTag is located. Then a SpaceTag client terminal will be like magic glasses to see SpaceTags. It is a very natural way of enhancing the SpaceTag System. Even if this kind of enhancement is implemented, old terminals without an orientation sensor will still be available. This is what we mean by *backward compatibility*.

By the way, after such enhancement, a SpaceTag object will have more reality, since it is placed at a very precise location. Then it will be a nice idea to use a SpaceTag to represent a virtual creature. It is very natural that a virtual creature can interact with other creatures and real humans. One of the aspects of active SpaceTag design is a preparation for virtual creatures.

Another interesting aspect of the active SpaceTag is to enable message passing between SpaceTags. In other words, we can regard SpaceTags as cooperative agents, or existing cooperative agents can be projected into the world of SpaceTags, which are visible in the real world.

Our design goals of the active SpaceTag are:

- To give general and natural user interfaces appropriate for SpaceTags including virtual creatures.
- To avoid attaching new hardware devices to client terminals as much as possible.
- To give an integrated interaction framework to both between SpaceTags, and between a SpaceTag and a human.
- To give a same basic design for both current early prototype (with low precision and narrow bandwidth) and future products (with high precision and wide bandwidth).

3.2 Model

We have adopted the awareness model given by Benford [3]. He gave three subspaces to an object in a virtual space: *aura*, *nimbus*, and *focus*. However, in our current implementation, it is simplified by regarding aura and focus as having a same value.

In early sections in this paper, we wrote that a SpaceTag has an attribute of effective zone, but it was a simplified description for easy understanding. Correctly speaking, a SpaceTag has attributes of *nimbus*, and *focus*. In our case, nimbus, and focus are functions of the distance from the location of a SpaceTag. A user (i.e., a client terminal) also has these attributes.

Let the value of SpaceTags A's nimbus at location P be *nimbus(A, P)*, the value of SpaceTag A's focus at location P be *focus(A, P)*, and the location of SpaceTag A be *loc(A)*. Then, an appearance of SpaceTag A to SpaceTag B depends on the pair of *focus(B, loc(A))* and *nimbus(A, loc(B))*, following Benford's basic idea.

3.3 Mutual Action between SpaceTags

An active SpaceTag can give an action to other SpaceTags. Mutual actions are modeled in two ways (Figure 7).

Let us consider cases of virtual creatures. A creature can talk to another (i.e., to send a message text), give something to another, or even hit another. These actions can be modeled by message passing, as usual cases of object oriented models. Whether SpaceTag A can send a message to SpaceTag B or not is depending on the type of message, *focus(A, loc(B))*, and *nimbus(B, loc(A))*. For example, A can talk to B if B is not very far from A, but A cannot hit B unless B is close enough to A.

Another option for mutual action is modeled by the *feeding metaphor*. With this metaphor, SpaceTag A creates SpaceTag C and puts C near the location of A. If SpaceTag B finds C, B can look at or consume C (i.e., detach C from the space). In this case, B can be affected by the content of C. It looks like that A feeds B, so we call this a feeding metaphor.

Feeding is different from message passing because any other SpaceTags may find the feed object and steal it. Even if the feed is not stolen, other SpaceTags can look at the feeding action. Hence it is more resemble to cases in the real world. However, feeding is more costly and time-consuming than message passing because the feed should be broadcasted to users.

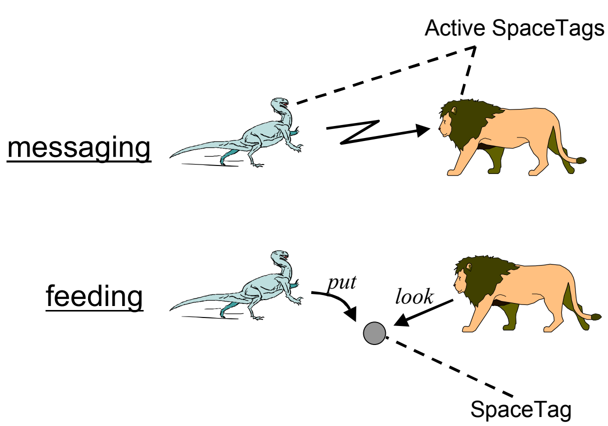

Figure 7. Mutual Action Models between Active SpaceTags

3.4 User-SpaceTag Interaction

As described above, a user also has attributes of nimbus and focus. Interaction between a user and a SpaceTag can be modeled in the same way as mutual actions between SpaceTags. The feeding metaphor can be applied in the same way, because operations of creating, sticking, seeing, and detaching SpaceTags have already been implemented in the passive SpaceTag system.

For message passing, we give user interfaces to send and receive messages. This is realized by temporarily moving a SpaceTag operation from a server to a client terminal and giving an interface for conversation between the SpaceTag and the user. An example of such interface will be shown in section 4, as a SpacePet interface. An active SpaceTag can accept commands from the user. This means that the SpaceTag receives a message from the user. Messages from the active SpaceTag to the user are shown as a text.

3.5 Human Communication through Active SpaceTags

As described in section 2.6, even passive SpaceTags can be used for human-human communication, by attaching SpaceTags made by a user onto the real world. With active SpaceTags, we can support more patterns of human communication and collaboration.

For example, one can create a SpaceTag that can interact with unspecified people in a town. If the SpaceTag asks some questions to people and collects their answers, the SpaceTag can make a questionnaire survey. Another example is an active message. A user can leave a message at a place in the real world as an active SpaceTag, like "I want to sell my old book." Since the message is active and have computational power, it can negotiate with candidate buyers about the price. This style of negotiation can be found in agents for e-commerce on the Internet, but active SpaceTag is more suitable at real marketplace like a flea market where people want to exchange things quickly, looking at real items for sale.

3.6 Implementation

As is the cases of usual SpaceTags, active SpaceTags are stored and managed within a server. To implement the message passing feature easily, an object relational database (ORDB) system is adopted for the SpaceTag database.

We have introduced two kinds of triggers that invoke *methods* of SpaceTags. One is the time trigger, the other is the space trigger (Figure 8). The time trigger is caused by a clock. The space trigger is caused when the SpaceTag has moved to a special area, or when a particularly specified other SpaceTag has moved into the focus of the SpaceTag. Of course methods are also triggered by incoming messages.

If a new SpaceTag is created and placed, other SpaceTags around it are given space triggers to have a chance to recognize it as a feed. If a message is passed from a SpaceTag to another, a *method* is invoked at the receiver side. Since these computations are all done within the server, no cost will be spent for communication. Mutual actions are managed on the server, and they are just projected onto the real world coordinates. Users observe the projected images.

Additional communication costs may be required when information on a newly created SpaceTag (feed) is broadcasted to users. The amount of communication cost depends on the frequency of information refreshing.

Anyway, client terminals do not have to be equipped with additional hardware devices. Only software to interact with active SpaceTags is required.

4. SPACEPET: AN APPLICATION OF ACTIVE SPACETAG

4.1 Design

In this section, we will show an application of active SpaceTag. It is an entertainment application with virtual creatures, called SpacePet. A user has a virtual pet, called a SpacePet, which is implemented as an active SpaceTag. A SpacePet can walk around the user, interacting with other users and SpacePets, finding and looking at other SpaceTags. In some cases, a SpacePet grows and changes its nature, according to its experiences.

There are some other entertaining systems that support virtual pets [14,15]. The most interesting aspect of our SpacePet is that a SpacePet is living in an open world. In case of existing virtual pet systems, only members of a pet system or residents of a virtual world can recognize a pet. However, in case of SpacePet, a pet can be found by a user who does not know well about the pet system, if the user is around the location of pet and selects the pet

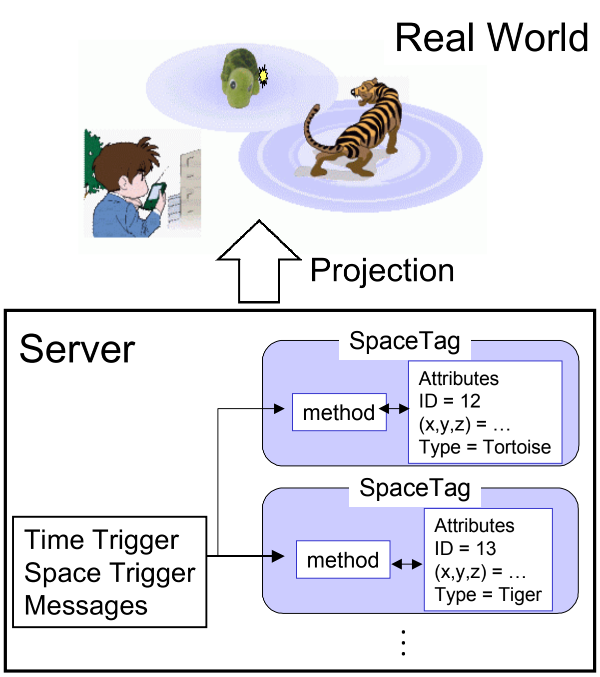

Figure 8. Triggers for Active SpaceTags

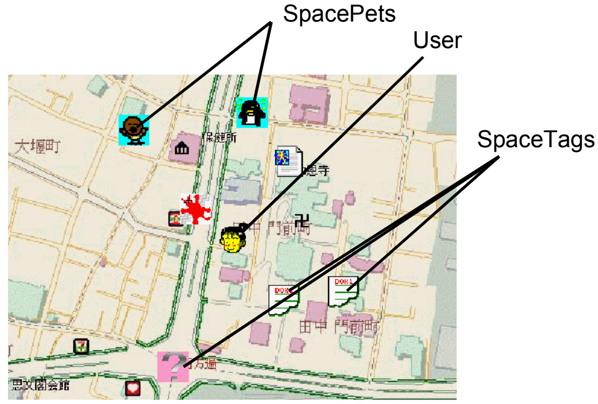

Figure 9(a). A SpacePet User Interface (1)

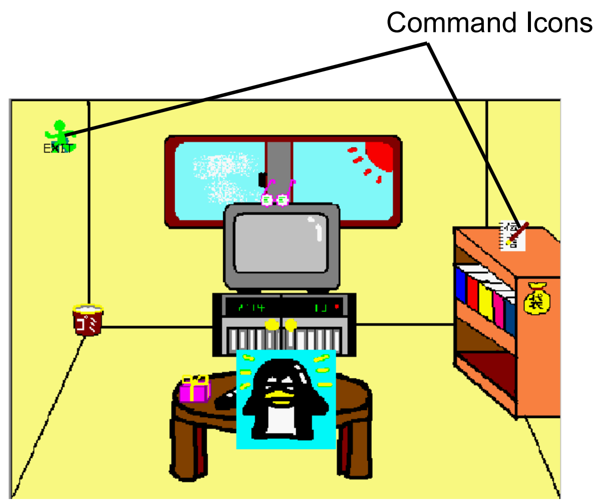

Figure 9(b). A SpacePet User Interface (2)

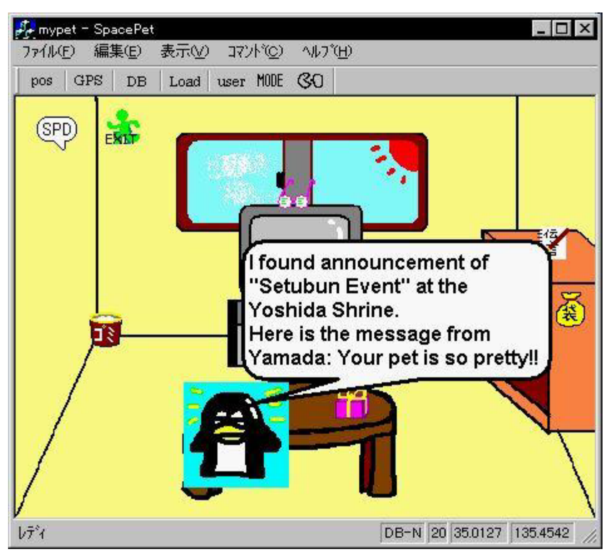

Figure 9(c). A SpacePet User Interface (3)

channel. For example, a tourist visiting your town, who is seeing a SpaceTag about a sightseeing spot with his/her SpaceTag-aware terminal, may find your pet walking there and talk to it. This is the difference between conventional CVE systems and overlaid virtual systems.

For the same reason, a SpacePet may find other SpaceTags. For example, your pet may find an advertising SpaceTag presented by a shop and report it to you. In this case, you can enjoy a real benefit, thanks to a virtual creature. The concept of overlaid virtual system gives us this interesting aspect: a mixture of real and virtual worlds.

Figure 9(a) is a snapshot of SpacePet user interface. The user is shown at the center of the map with a face icon. SpacePets are moving around the user, shown by animal icons. There are also usual SpaceTags around the user. SpacePets are dealt with in the same way as other SpaceTags, unless time or space triggers occur, or the user accesses the SpacePet.

A SpacePet walks about in the city and gains many experiences: talking to or fighting with other pets, interacting with human users, looking at SpaceTags stuck in the city, etc. It will report its experiences when it returns to its owner.

If the owner accesses a SpacePet, the SpacePet returns to its room in the portable terminal. Then a window as shown in Figure 9(b) appears. The user can give commands to the SpacePet by clicking command icons placed in the room. If the SpacePet has something to talk to the user, the message will be given to the user as shown in Figure 9(c)[3]. Here, the penguin is talking to the user about a SpaceTag he found at the Shrine, and about a message from Yamada.

4.2 Communication through SpacePets

As we have already mentioned, the most significant nature of SpacePets is that they are living in the real world, not in the virtual world, although they are virtual creatures. Even people who are not interested in the virtual world may find and communicate with SpacePets, if they are SpaceTag users. Moreover, SpacePets can find other SpaceTags stuck on the real world, which have information related to the real world.

With these reasons, SpacePets enhance communication among people in the real world. For example, a person can give a message to another person, by using his/her SpacePet as a messenger. On the contrary, a SpacePet can get an unexpected message from a person who happened to meet the SpacePet, and give the message to its owner. Moreover, your pet may have a conversation with other people's pets and report it to you; this gives you chances to find new friends.

To summarize, SpacePets, or active SpaceTags support human communication in the real world as non-active SpaceTags can do, but they are more powerful in the sense that they give more chances for unexpected, accidental, and wide-area communication.

[3] We are not proud of the artistic design of user interface. It was designed for prototyping by one of our project members, who is a student belonging to Computer Science course. We strongly want to redesign it.

5. CONCLUDING REMARKS

In this paper, we have described an overlaid virtual system SpaceTag and its enhancement with active SpaceTags. Overlaid virtual systems are easier to popularize than other types of augmented reality systems, because it costs low, has an easy-to-understand metaphor, gives natural user interfaces, is general-purpose, and also is easy to make business models [11]. By the active SpaceTag enhancement, which is also low cost, more applications including SpacePet are available.

Even now, the SpaceTag System is almost technically ready to start as a small trial service with terminals like EPSON's Locatio and cellular phone communication channels. However, to start a large-scaled service, we still have some problems that should be solved by governments or big companies.

- **Location sensing system:** GPS is not available underground or in buildings. PHS has low precision as a location sensing system. A universal location sensing service is needed to enable the SpaceTag System and other location-aware services.

- **Down-link communication channel:** To give a more broadband SpaceTag service, more digital broadcasting or communication channels should be reserved for this service. In case of Japan, most analog broadcasting channels will be released in year 2010 (as our government's current schedule). IMT-2000 mobile phone standard is also a possible solution.

In spite of these unsolved problems, we strongly believe that the overlaid virtual architecture is the most successful approach to public and open services like augmented or virtual reality.

As a CVE system, the SpaceTag System has a very special feature, in the sense that it has the same time/location coordinates with the real world. With this feature, we have some advantages:

- Some people do not like to go into a virtual world in a computer display. Using SpaceTags, more number of people can be involved in a CVE.

- The world is open-ended.

- Communication between people is activated, triggered by real world's objects and events.

- Walking in the real world is more healthy than walking in a virtual world (but sometimes people get exhausted).

As for the SpacePet, we are expecting that it will be a popular application of multimedia technologies in future. Consider a future world where robots play roles of public servants. This kind of situation has been often described in novels and, actually, there are researchers who are designing such robots. It is really exciting. However, robots are physical objects. They are costly, fragile, not flexible, and even obstructive to people who do not need help. Unless physical labor is expected, virtual objects, i.e., SpacePets, can replace them. They will be walking in a town or will suddenly appear if summoned, helping people as public servants. They are very flexible, low cost, and not obstructive. Only people who really need them, i.e., people who select a particular channel of the SpaceTag System, can see them. This is our final goal in future.

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