MR-based Virtual City with 3DSpaceTag

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Abstract. In this paper, we will propose a new type of digital city, where data objects are shared by people using a mixed reality (MR) mechanism, rather than the Internet. Our simple MR mechanism is called SpaceTag. An important aspect of SpaceTag is that GPS-enabled cell phones on the market can be users' terminals, so that huge number of potential users can join. We have conducted some experiments for evaluation. The results of experiments suggested that it is possible and interesting to build a virtual city overlaid onto the real city with the SpaceTag mechanism. We have introduced 3D Objects as SpaceTag objects; the system is called 3DSpaceTag. This paper describes the design and evaluation result of 3DSpaceTag. A trial application of 3DSpaceTag to a digital city is also described.

1. Introduction

In the report of the last Digital City Workshop, the editors gave three types of concepts of digital cities: (1) a representation of a real city, town or village on the Internet, offering citizens all kinds of information about the real city, as well as possibilities for communication and social interaction, (2) a city with an advanced information and communication infrastructure needed to catch up with the global economic dynamics, or to revitalize the local or regional economic structure, (3) systems that use the city metaphor like virtual communities for collaboration or for playing games[1].

We are trying to create a new type of digital city. In our case, a set of data objects is given to people through a mechanism of *mixed reality*. People can find some virtual objects only when they visit a particular place in a real city, if the virtual objects are related to the place. It is different from the first type of digital city concept, because the real city is not represented on the Internet, but used as it is. The second concept can logically include our system, but it is not straightforwardly describing ours. Economical effect is expected, but is not our main target. Our goal is to give a technological infrastructure. The third concept is partly describing our goal. We are expecting many applications on our infrastructure, like community support, sightseeing guide, advertisement, entertainment, gaming, etc. However, a city is not used as metaphor but used directly.

In a usual sense in the research community[2-5], mixed reality means a mechanism that precisely locates a virtual object in the real world, and presents it to users through high-tech devices like a head mounted display. This type of mechanism is technically interesting, but it is too expensive to involve many consumers now (and also in near future). For consumer applications like digital cities, terminals should be as cheap as possible. Infrastructure cost, including communication facilities, should also be inexpensive to cover wide area.

We adopted GPS-enabled cell phones for consumer terminals. In Japan, there are more than 6,000,000 users of GPS-enabled (and internet-accessible) cell phones. Market price of such a phone is 10,000-20,000 yen (US$ 80-170). Our policy is not to attach any other devices to the phone, to avoid extra mental and economical barriers. Of course, we cannot give precise location of virtual data objects by only using such phones, because GPS has errors and because neither digital compasses nor accelerometers are attached. We do not use a head mounted display to show an overlaid image of virtual and real objects. With all these reasons, our system is very cheap and simple, but it is still a mixed reality system in a logical sense.

In this paper, we introduce our trial of this approach to digital cities. In section 2, we will introduce the SpaceTag system and its evaluation. The SpaceTag system manages data objects with location attributes, and distributes them to people in a limited geographical area. In section 3, we will introduce 3DSpaceTag, which is a 3D version of the SpaceTag system. It can handle 3D objects and locate it at a particular position in the real world. Users can browse a virtual 3D object using a GPS-enabled cell phone, according to its relative position from the object. An evaluation session has shown that 3DSpaceTag can be used at least for some applications. In section 4, a prototype of virtual city with 3DSpaceTag will be introduced. On the prototype system, a set of virtual buildings and creatures are represented as 3DSpaceTag objects. Visitors can browse the virtual city objects with GPS-enabled cell phones. We will conclude this paper in section 5.

2. Simple SpaceTag and its Evaluation

SpaceTag is a server-client system that distributes information objects to portable terminals, according to the location (latitude, longitude) parameters of objects. For example, if an object has (x, y) as its location parameters, only users near (x, y)[1] can access the object. An interesting aspect of SpaceTag is that objects can move about in the real world, by changing the location parameters periodically. Both organizational information providers and end-users can give such information objects; i.e., SpaceTag is a bi-directional medium. As shown in Fig. 1, we can create virtual worlds, each of which is defined as a set of SpaceTag objects, and overlay them onto the real world, according to geographical locations. Users of SpaceTag can subscribe one or more virtual worlds and browse objects in these worlds with portable terminals such as

[1] The definition of *nearness* can be given as a polygon or a circle.

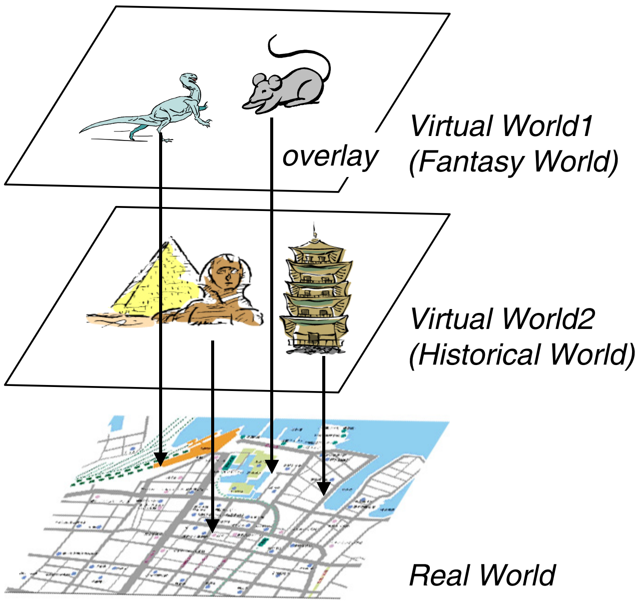

Fig. 1. Overlaid Virtual System Concept

GPS-enabled cell phones. We call it as the overlaid virtual system model. For more information, see previous papers [6-8].

Currently, we have both experimental and commercial service of SpaceTag. Available terminals are GPS-enabled cell phones. A piece of virtual object is called *tag*. HTML text including small still images is available for tags.

We conducted evaluation sessions employing twenty subjects in a Japanese garden (*Ritsurin Park*, a sightseeing spot in Takamatsu city) and on a shopping street. Subjects were given two kinds of settings, using and not using the SpaceTag system. In case of SpaceTag, pieces of information on sightseeing spots or stores are distributed only to limited locations, whereas in case of not using SpaceTag, all information is distributed to all locations. Both in the park and on the shopping street, about half subjects supported SpaceTag, and the rest of half supported the other. Typical reasons of supporting SpaceTag were that it was exciting, and that information not related to the location was suppressed.

We also asked the subjects whether you felt that the information existed there or you felt the information was just sent from a server. Subjects tended to feel that the information existed there, with a supporting T-test result ($p<0.05$). This fact suggests that SpaceTag gives a kind of mixed *reality*, only by limiting the area of information distribution.

3. 3DSpaceTag and its Evaluation

With 3DSpaceTag, we allow 3D objects to be *tags*. This means that a user can see different appearances of an object depending on the relative position and direction from the object. It is an MR system in the sense that virtual objects are logically located in the real world, like the Augrscope[5].

3.1 System Configuration

The 3DSpaceTag server, this time, is a PC (Pentium 4, 1.7GHz) with Windows 2000 Professional OS, Apache web server, and a Servlet mechanism with Tomcat 4.0. Its configuration is shown in Fig. 2. The Servlet mechanism invokes a Java module linked with the Java3D library, when a client sends a request to view a 3D object with the client's location (latitude, longitude) parameters. The module generates a 2D image of the 3D object that is the appearance of the object when viewing from the location. The 2D image is a PNG data of 120 x 120 dots, which is a common size displayable to small displays of cell phones.

A 3D object can be designed using LightWave 7.5, which is a popular authoring tool for 3D objects. Adopting LightWave enables the system to provide attractive objects, which compensates for the disadvantage of display size.

We used CASIO A3012CA, a product of GPS-enabled cell phone, as terminals. Its communication technology is CDMA 2000 1x. Communication speed is 64kbps for uplink and 114kbps for downlink. Of course it has the gpsOne function. It weighs only 120g. It also has a CCD camera, but we did not use it since it cannot be controlled by software without knowing confidential specification.

From a user's viewpoint, this system can be used as follows. When a user tries to access the 3DSpaceTag server by giving the URL of this system, the gpsOne function is automatically activated (Fig. 3(a)). The phone terminal detects its location by communicating with the gpsOne location server, and sends the location parameters to our 3DSpaceTag server. The 3DSpaceTag server returns a list of 3D objects accessible from the user's position (Fig. 3(b): the right image is the lower-half of the scrolled image.). A list item consists of a title, a direction, and a distance value. A direction is given from eight values, N, NE, E, SE, S, SW, W, or NW (in Fig. 3, they are shown in Japanese). A distance value is given in meters. When the user clicks one of the listed objects, the 3DSpaceTag server generates the 2D appearance image of the object and returns it to the user's terminal (Fig. 3(c)). From (b) to (c), it takes about 3 seconds at the server side. Total response time heavily depends on the condition of the mobile network system; but typically it is about 7 seconds. This seems to be long, but it is much shorter than the time necessary for the gpsOne function (about 20 seconds).

After getting an image like Fig. 3(c), the user has to face the indicated direction (e.g., west), stretch one's arm horizontally with the cell phone terminal in hand. Then, what the user sees on the phone's display is the virtual object located in the direction.

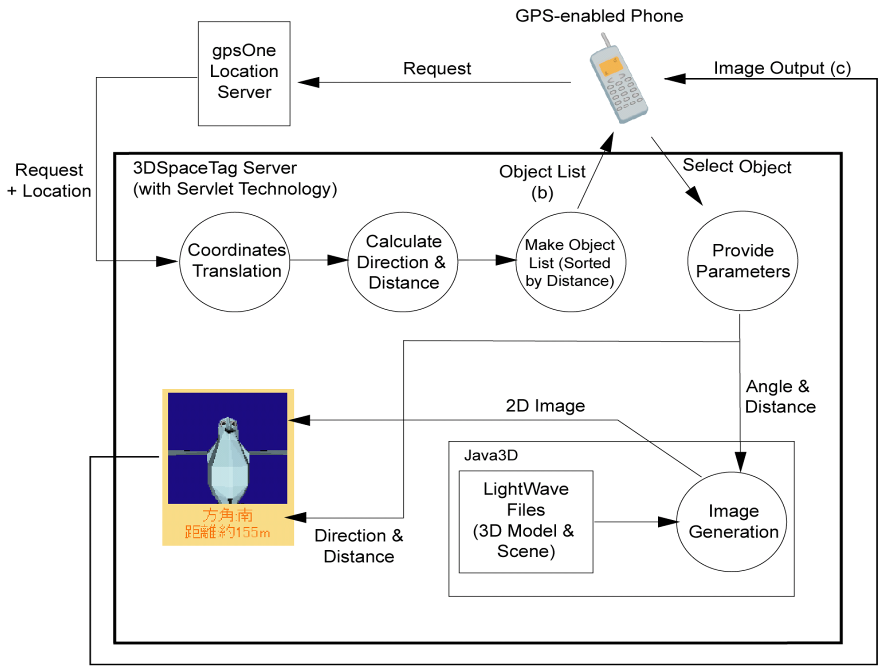

Fig. 2. 3DSpaceTag Server Configuration & Mechanism

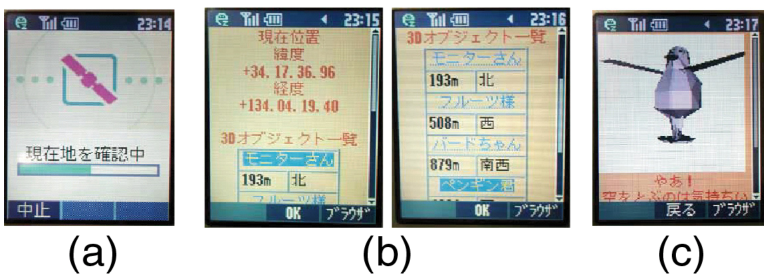

Fig. 3. User Interface

3.2 Examples of Generated Images

To demonstrate and validate the 3DSpaceTag system, we had a field test session. A virtual bird was placed at (N 34.17.42.90, E 134.04.17.80). The bird stood southward. We viewed the objects with the 3DSpaceTag system from locations shown in Fig. 4. In the area where we had this and next experimental session, the gpsOne function had about 10 meters of errors. Table 1 (in Appendix) shows all images observed from each position.

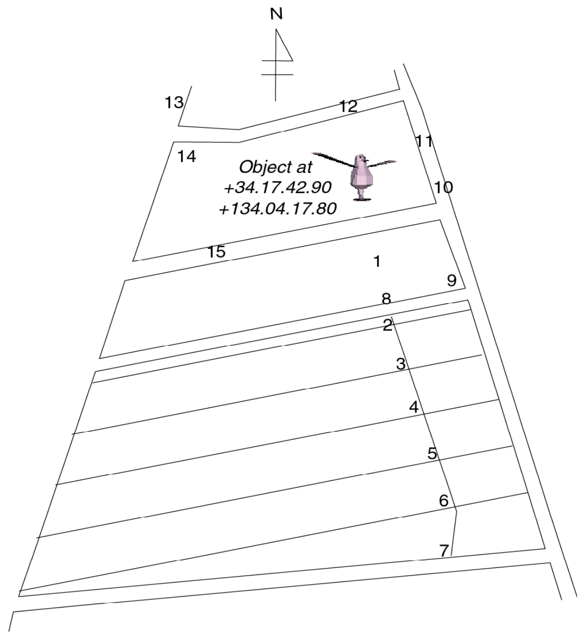

Fig. 4. Locations of Observation for Table 1

As shown in Table 1, 3DSpaceTag gives fairly good and natural images to the phone terminal. In case of location #1 and #12, the bird's utterance is shown below the image, just because the distance is less than 200 meters.

3.3 Evaluation by Subjects

We had an evaluation session employing fifteen subjects. They were university students, whose ages were from 20 to 23. Ten of them were males and five were females. As usual cases in Japanese young generation, they were using cell phones for e-mail and accessing the Web service everyday.

As shown in Fig. 5, we put four 3D objects around Kagawa University (marked as a star symbol).

We let the subjects freely walk about in the area of experiment and observe 3D objects. After each subject had an experience of 30-60 minutes, we gave a questionnaire. The questionnaire included some questions that should be answered according to the five-grade system (5 is the best score). Some interesting results are shown in Table 2.

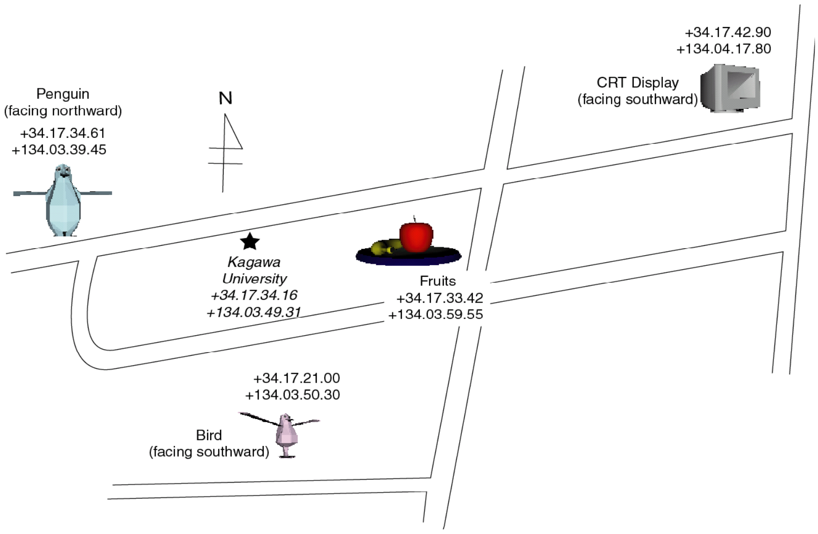

Fig. 5. Map for the Experiment with Subjects

Table 2. Questionnaire Result for 3DSpaceTag

Question	Mean Score (5.0 is best, 1.0 is worst)
Did you feel a perspective view?	4.6
Did you feel that you could approach or go away from a virtual object?	4.6
Did you feel that the object was 3D?	4.3
Did you feel that a virtual object was really there?	3.3
Do you think that it is attractive to watch 3D object with cell phones?	4.3
Did you feel it interesting that there were 3D objects in the virtual world?	4.5

The fourth question did not take a good score. Some subjects suggested that this score was mainly due to lack of the function of overlaying virtual object to the real world background. This problem can be resolved by providing overlaid image of virtual objects and real image taken by a CCD camera embedded in the cell phone, if the camera's specification is disclosed. However, it will be possible that an overlaid image badly emphasize the errors in location and orientation detection. It should be our future work to find a low-cost solution of this problem.

In spite of this problem, all subjects reported that this system was attractive. The last two questions took good scores that show they generally had good feelings to the virtual world. This fact encouraged us. Providing 3DSpaceTag to the public now seems to be much better than waiting for a new technology.

4. Virtual City with 3DSpaceTag

4.1 Concept

With the 3DSpaceTag system, people can view virtual 3D objects overlaid onto the real world, from any location in the real world. By introducing multiple objects like virtual buildings and creatures, we can create a virtual city, which can be viewed by GPS-enabled cell phone users.

A 3D virtual city overlaid onto the real city would be used like the following example applications.

- Historical buildings that do not exist today can be virtually reconstructed. It will give a new stimulus to the tourist industry.
- City planning can be visualized and open to the public.
- Virtual creatures living in the virtual city can give new ways of entertainment and communication to people. For example, people will meet a virtual creature in a city and have some interaction. A virtual creature may be an avatar of another user [7]. It will be also possible to move a virtual creature within the virtual city.

4.2 Implementation

We have implemented a prototype system of a virtual city. In this system, a virtual world containing virtual buildings and virtual creatures is managed in the server. Different from the earliest version of 3DSpaceTag system described in section 3, multiple objects can be viewed at once on a cell-phone terminal.

When a user visits this system from a particular position in the real city, a directional index like Fig. 6 is shown. Directions in which any objects exist are underlined to show that it is clickable. If the user clicks a direction, an image of virtual city in the direction viewing from the particular position is created on the server and sent to the terminal (see Fig. 8 in Appendix).

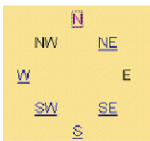

Fig. 6. An Example of Directional Index

Drawing multiple objects is implemented by directly using the scene graph mechanism of the Java3D library. Hence the system architecture is basically same as Fig. 2, except for:

1. The Java3D library reads a scene graph including multiple objects instead of a scene graph with only one object.
2. A horizon object is given.
3. A directional index is used instead of a sorted list of objects.

4. A user selects a direction instead of selecting an object.

4.3 Example

Overlaying onto our university campus, we created a virtual city. Fig. 7 is the map of the city. Star symbols show locations where sample images in Fig.8 (in Appendix) were taken.

There are four buildings (House A, House B, House C, and bureau), two virtual creatures (dog1 and dog2), and one signboard (Map) in the virtual city. Although not shown in Fig.7, a pyramid-like tall building (supposed 140m high) is placed about 400m away from the shown buildings in the south direction. It is shown in Fig.8 (b)'s "south" image.

For this prototype, we did not implement any active functions to virtual creatures (i.e., dogs). Hence they cannot move or actively talk to users. However, each dog can give some utterances (implemented just as a HTML text) when a user approaches to it and clicks an extra link.

Since A virtual source of light (the virtual Sun) is in the south direction, the southern sides of virtual objects are brighter.

5. Conclusion

As shown in sections 2 and 3, SpaceTag and 3DSpaceTag give users a feeling of mixed reality in some senses (but not perfectly). We believe that they can be used for

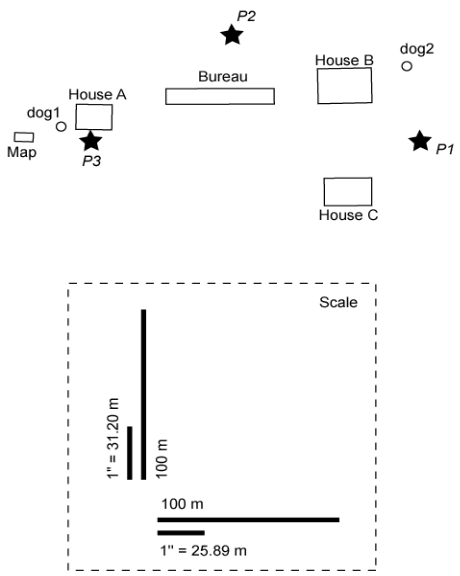

Fig. 7. A Map of Virtual City and Scale Measure

the platform of digital cities of our approach, where virtual objects are shared through the mechanism of mixed reality. Hence we have designed a prototype of virtual city system described in section 4.

What we want to do here is not to create a perfect virtual world, but to create a new type of exciting communication field that can involve more than 6,000,000 potential users. Taking advantage of the huge number of potential users who have GPS-enabled cell phones, we will open the virtual city to the public.

Actually the prototype virtual city seems to be an exciting one. Visiting virtual buildings and meeting with virtual creatures are attractive enough. However, the virtual city prototype described in section 4 has not been formally evaluated, yet. It is our future work. Especially, to evaluate influence of GPS error, to find better methods for recognizing direction, and to design better ways for sunshine protection are future issues. Also, to speed up rendering, techniques like LOD (Level of Detail) or 3D graphics engines should be introduced.

With all these future work, however, we are convinced that the virtual city system is useful for at least limited applications. For example, viewing the appearance of the city of hundreds years ago from an observatory is a case that allows some GPS errors. In that case, directions are usually given to users by an alternative way (i.e., by a signboard) from using electronic or magnetic compasses.

We are also planning to implement active functions for virtual creatures (agents). For example, scenario-based interaction to users and autonomous movement are under design now.

Commercial, economical, social, and even law issues should also be discussed and evaluated in future. Different from conventional virtual worlds on the Internet, like online games, virtual buildings and creatures are always have some relation to real world objects, which is the interesting point of this type of virtual city. We will welcome visiting researchers of various fields to our virtual city.

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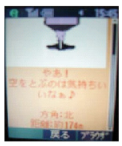
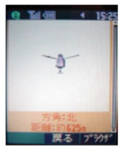
Appendix

Table 1. Generated Images for Locations in Fig. 4.

Location #	1		2	3
Generated Image				
Latitude of User	+34.17.37.28		+34.17.33.66	+34.17.29.87
Longitude of User	+134.04.17.17		+134.04.18.09	+134.04.18.48
Direction of Object	N		N	N
Distance	174m		287m	405m

Location #	4	5	6	7
Generated Image				
Latitude of User	+34.17.26.97	+34.17.22.89	+34.17.19.08	+34.17.16.47
Longitude of User	+134.04.19.39	+134.04.20.25	+134.04.21.23	+134.04.20.27
Direction of Object	N	N	N	N
Distance	497m	625m	745m	823m

Location #	8	9	10	11
Generated Image				
Latitude of User	+34.17.35.28	+34.17.38.89	+34.17.44.40	+34.17.47.58
Longitude of User	+134.04.17.27	+134.04.25.76	+134.04.25.06	+134.04.23.63
Direction of Object	N	NW	W	SW
Distance	236m	250m	204m	218m

Location #	12	13	14	15
Generated Image				
Latitude of User	+34.17.46.23	+34.17.48.54	+34.17.45.16	+34.17.34.99
Longitude of User	+134.04.14.87	+134.04.05.28	+134.04.07.78	+134.04.10.57
Direction of Object	S	SE	E	NE
Distance	145m	342m	242m	294m

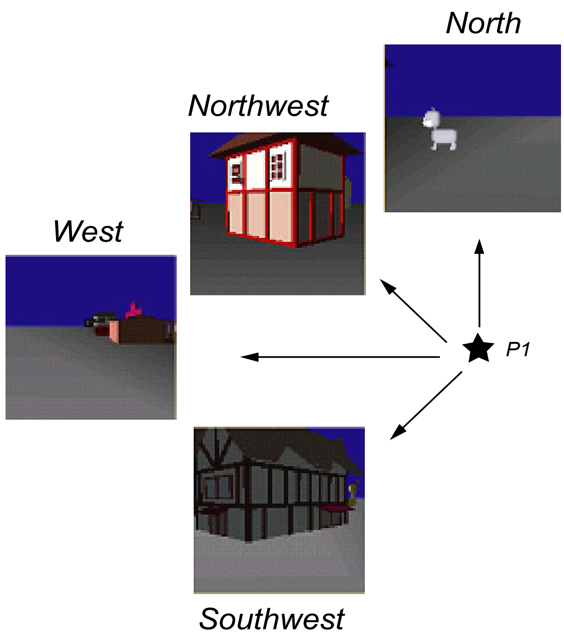


Fig.8. (a) An Example of Virtual City Viewing from P1

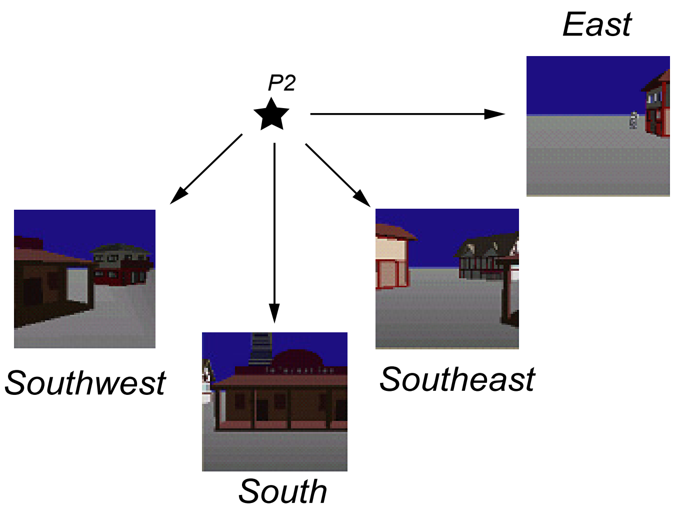


Fig.8. (b) An Example of Virtual City Viewing from P2

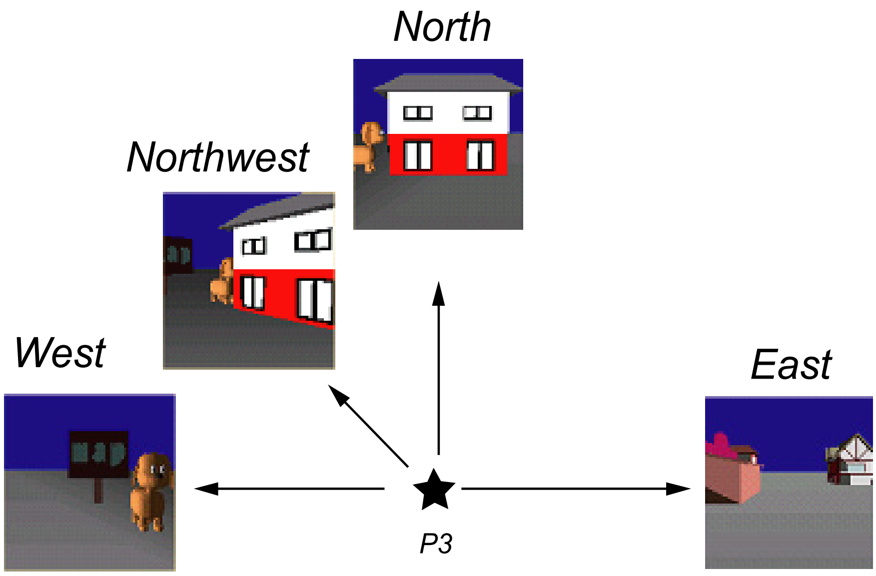


Fig.8. (c) An Example of Virtual City Viewing from P3