A Position-Adaptive Broadcasting System for Moving Terminals that Accommodates Different User Requirements

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Abstract : **In this article, we propose a position-adaptive broadcasting system for moving terminals where metadata that provide summaries of local information and the location of actual content are distributed by broadcasting (Push type), while the entity of content is selected and acquired by the receiving terminal via manual or automatic communication (Pull type) depending on the terminal's velocity and direction of travel. We demonstrate the effectiveness of the automatic selection function of programs using simulations. With this system, it is possible to realize a portable terminal which enables not only the selection of broadcasting programs at various granularities but also allows overseas programs to be received easily.**

1. Introduction

Japan's domestic satellite broadcasting system is already being employed to supply position-adaptive broadcasting services featuring customized information such as post-code based weather forecasts. However, the granularity for expressing position is fixed beforehand, preventing the use of settings that would respond to more specific user needs. In addition, relying on only the broadcasting network to meet different user needs, including change of granularity, requires a wide broadcasting bandwidth, a large storage capability in the receiving terminals, and the further disadvantage of a long latency time for acquiring the information.

In this article, we propose a position-adaptive broadcasting system for moving terminals where metadata that provide summaries of local information and the location of actual content are distributed by broadcasting (Push type), while the entity of content is selected and acquired by the receiving terminal via manual or automatic communication (Pull type) depending on the terminal's velocity and direction of travel. We demonstrate the effectiveness of the automatic selection function of programs using simulations. With this system, it is possible to realize a portable terminal which enables not only the selection of broadcasting programs at various granularities but also allows overseas programs to be received easily.

2. A position-adaptive broadcasting system for moving objects

2.1. A position-adaptive broadcasting services that accommodates different user requirements.

In conventional TV broadcasting, position-adaptive broadcasting services have not been capable of customizing information except according to fixed granularity determined by post-code[1]. To meet various user needs in the future, the granularity of expressing position needs to be freely specified. For example, coarse granularity for specifying a country unit, and fine granularity for latitude and longitude. By specifying the country unit, overseas local news are displayed and by selecting latitude and longitude, locally restricted information such as neighboring shops or sightseeing places are provided to users. In conventional TV broadcasting, its contents are targeted for various general users in all categories in view of its public roles. This article describes a realizing method of broadcasting service capable of specifying the position in various granularities to meet various user needs.

Assuming the use of portable terminals, we propose a system for moving objects featuring two ways of selecting broadcast programs : a) manual selection of contents by manual selection of the granularity (country, prefecture, post-code, latitude and longitude) and b) automatic selection, acquisition and display of contents related to its current latitude and longitude according to its speed and direction.

2.2. Technical problems facing the proposed system

One technical problem when distributing content via the broadcasting network is long latency time due to bandwidth limitations, since the transmitting information volume is very large when the entity of content is expressed in various granularities. We extended the content distribution model of the TV-Anytime Forum[2], which combines a broadcasting and the communications network standardized for fixed terminals. We have realized broadcasting with a short latency time by distributing, as metadata, the relational description relating to summaries, not the entity, of content, addresses indicating their location and positional information (e.g. latitude and longitude) using the broadcasting network (Figure 1). Regarding the distribution system using both the communications and the broadcasting system, Hakomori et al. proposed a system for switching between them according to the access frequency to the data [3]. However, no study has up to now been conducted on using both broadcasting and communications networks for distributing position-dependent content to mobile terminals.

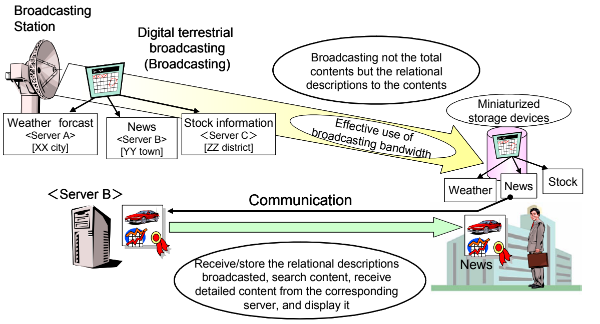

Figure 1: A position-adaptive broadcasting system for moving objects

In this article, the terminal receives and stores the relational description as metadata (e.g. summaries of content, addresses locating content such as URLs and positional information, etc.) through broadcasting. And the user searches the content manually or the terminal searches the content automatically according to its current position, and selects and downloads the entity of contents (e.g., moving pictures, sound and text) from the corresponding server via the communications network, then display them (Figure 2). Realization of this system will lead to more effective use of broadcasting bandwidth and reduced demand for storage capacity at the receiving terminal.

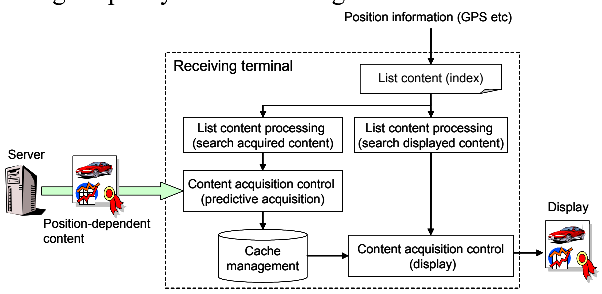

Figure 2: Structure of the receiving terminal

Next, we will clarify the technical problems in achieving this system assuming the usage scene of users. First, we will describe the assumed transmission environment. We assume that digitalized terrestrial broadcasting waves will be used for broadcasting, and that multiple wireless links such as third-generation cellular phones and wireless LANs will be used as communication paths (Figure 3).

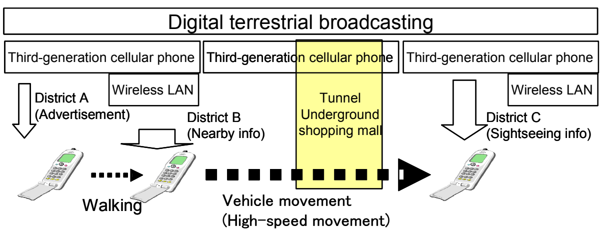

Figure 3: Contents distribution via different networks

Figure 4 shows the operational sequence starting from the reception of metadata about relational descriptions, to the contents acquisition and up to the display completion by the receiving terminal. The operational sequence, including user operations, can be roughly classified into the following four processes:

(1) Scheduling of contents acquisition

(2) Switching to different links, and disconnection of links in tunnels and underground areas

(3) Switching to programs at high speed (zapping)

(4) Display control

First, the terminal receives metadata about relational descriptions via the broadcasting network and searches nearby contents automatically according to its current position and determines the candidate contents, their order and timing for acquisition via the communication network (1). There are two possible ways to acquire position-dependent contents via the communication network: the streaming system [4] where contents are repeatedly sent with the carrousel and selectively received by the receiving terminal, and the downloading system where the terminal selectively acquires the necessary contents. In this article, we adopted the downloading system to suppress the contents acquisition delay, based on the results of past analysis [5].

Although the adoption of the downloading system may lead to an increase of the terminal's processing load, it allows the re-start process of contents acquisition to be easily achieved after a disconnection of the link caused by switching to a different link (e.g. from a third-generation cellular phone to a wireless LAN) based on the communication cost, and caused by usage in tunnels and underground areas (2). Concretely, since HTTP, which is normally used in downloading protocols, is capable of explicitly conveying the contents acquisition range from the receiving terminal to the sending terminal, the restart of the acquisition process for contents which have not been acquired at the restart of the link can easily be achieved. However, since conventional studies target stream transmissions and accomplish the restart process for stream transmissions at servers and relay nodes, special servers and relay nodes are required [6].

Further, in cases where the user browses nearby programs (contents) at high speed (manual program selection system), the delay to acquire the content of new desired programs via the communication network cannot be neglected (3). This article discusses a system in which the receiving terminal downloads, acquires and stores beforehand the nearby contents likely to be accessed by the user, allowing the user to switch to different programs at high speed.

Finally, with respect to display control, much like with high-speed switching between programs, the contents acquisition delay cannot be ignored and may significantly affect the contents display delay, depending on the contents acquisition scheduling system. When working with video contents, the display control which takes into account the time necessary to replay the content is required, and in addition, the acquisition scheduling considering the necessary replay time is also required. Further, in districts where the volume of contents is dense, it can be difficult to display everything. Therefore, such display and acquisition control is required where the contents to be displayed and acquired are filtered and determined from the received programs using not only the positional information, but the contents acquisition history as well as the type of programs attached to the contents list and the user's profile. The method for associating a type to a program's information has already been standardized in reference [7].

In consideration of the above points, we will describe the contents acquisition system in detail in the following chapter.

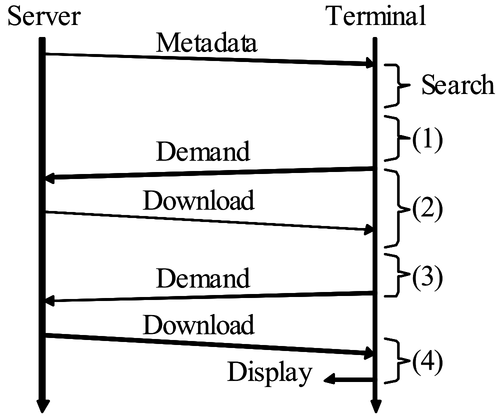

Figure 4: Operational sequence of contents acquisition

3. Realization of the automatic content acquisition function

3.1. Need for predictive acquisition

Below is a description of the characteristic features of the automatic selection system for programs which is capable of automatically selecting, acquiring and displaying content (broadcast programs) related to the latitude and longitude of the portable terminal. Especially contents acquisition scheduling is described in detail, based on the considerations highlighted in the previous chapter.

Position-related (position-dependent) content can be acquired using the communications network by searching and acquiring the content related to the position geographically nearest to the terminal.

We assume that the list content, comprising metadata describing the locations of multiple position-dependent content, have already been received by the terminal via the broadcasting network. However, if a terminal, especially in-vehicle terminals moving at high speed, attempts to search content related to its nearest position, it is moving during the search and the acquisition time, by the time that content is fully downloaded, it may no longer be related to the nearest position or may be unrelated to its current position.

A structured scheme to display contents within a specified period before mobile terminals pass by the position related to the content, allowing users to visually acquire the contents is required. Two points must be considered with respect to the factors causing a delay of the content display; one is the system latency and another is the time required from the start of content replay to its completion (time to replay). Regarding to system latency, you must take into account the time required to search for display content from the content list (search time) and the time required to acquire the displayed content based on the search results via a network (acquisition time). In this article, we describe a system to reduce the acquisition time through predictive content acquisition in response to the current position, the direction of movement and the speed. The method for achieving content acquisition and a function evaluation are described herein. High-speed search time is studied separately[8]. It is assumed that content comprises still pictures and text, and have a replay time of zero.

3.2. Previous studies on predictive acquisition systems

Among previous studies about predictive acquisition system by broadcasting, Sato et al. have proposed a system where in-vehicle terminals acquire content predictably along a scheduled route [9]; but there is no mention of the case where a car navigation system is not provided, i.e., when the scheduled route is not known. Ito et al.[10]proposed the selection of broadcasting content using a circular area with the current position as the center and with the radius determined by the speed of travel. In Ito's system, however, the direction of movement is not considered. Ishikawa et al.[11] proposed the selection of content using an elliptical area with two focal points comprising the current position and the target position ahead of the moving direction, but the relationship between velocity and the elliptical area is not described.

All these previous studies discuss only the case where position-dependent content is distributed via only broadcasting. The receiving terminal carries out both the scheduling of the acquisition of content based on the broadcasting period and the storage management. Consequently, no study has yet been made concerning the predictive acquisition of content using a communications network to enable immediate content acquisition requests from the receiving terminal, as covered in this article.

3.3. A velocity and direction-adaptive predictive acquisition system

In this article, we propose a velocity and direction-adaptive predictive acquisition system which is capable of selecting and acquiring position-dependent content and displaying it to users without delay, regardless of the speed of movement and the moving direction of the terminal, even if the scheduled route has not been specified beforehand.

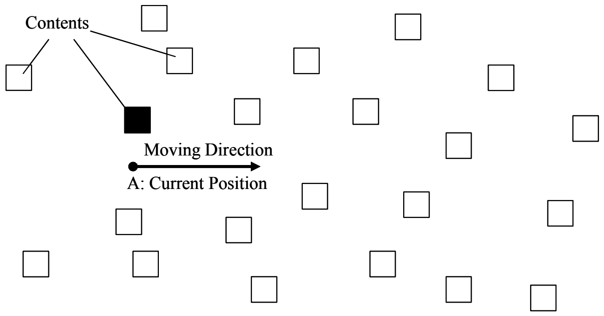

Figure 5: Relationship between the terminal and content locations

Figure 5 shows the relationship between the terminal and content locations. The terminal is currently located at position A and is moving towards the right. Around the terminal, units with position-dependent content are shown as squares. The terminal attempts to display the nearest content to itself (the black square), but as it moves during the display delay time due to the time required for acquisition, when the acquisition is completed, content trails behind the terminal and its usefulness has declined.

The outline of the system is shown in Figure 6. Our proposed velocity and direction-adaptive system displays the targeted contents in the broader moving direction area so that they can be displayed before the mobile terminals pass by the position related to the content. Here, the ellipse E_2 with two focal points, comprising the current position A and point B, ahead of the moving direction, is designated as the content display zone.

Further, in order to eliminate delays in the acquisition time to display contents, the contents in the broader area than E_2 are targeted for predictive acquisition, acquired predictably and stored. More specifically, in order to respond to changes in direction, the ellipse E_1 with two focal points, comprising the current position A and point C, ahead of the moving direction, including content beside and behind the moving direction of the terminal, is set as the content acquisition zone.

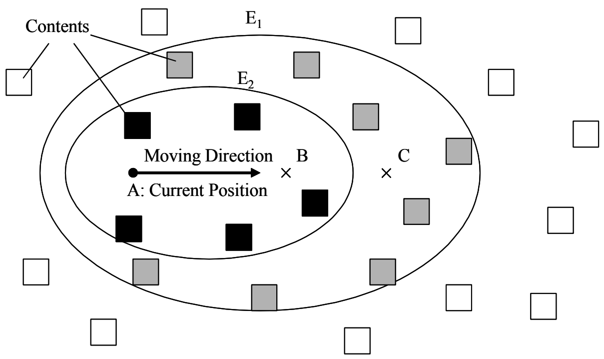

Figure 6: Outline of the velocity and direction-adaptive predictive acquisition system

In this system, because a broad area, ahead of the moving direction of the terminal, is targeted for display, contents can be displayed before the terminal passes by the position related to the content. The content within the content display zone E_2 (black squares) can be selected from the predictably acquired content within the content acquisition zone E_1 (gray and black squares) and displayed without delay, resulting in no acquisition delay because the content was stored inside the terminal prior to being displayed.

Further, the sizes of the content acquisition zone and the content display zone can be adjusted by changing of focal point B and C against the current position A according to the velocity. As the travel speed increases, contents located further ahead are required within a shorter period time. In order to respond to this change, when the speed is increasing, focal point B and C are set further ahead to enlarge the content acquisition zone and content display zone. When the speed is decreasing, focal point B and C are set nearer to contract both zones. Therefore, changing the target contents by changing the sizes of E_1 and E_2 is expected to cope with the changes in travel speed and provide users with contents in a shorter delay.

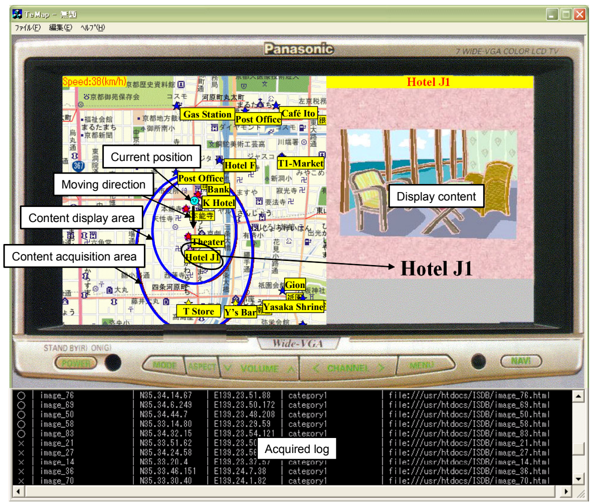

Figure 7: Display example of the experimental System

3.4. Evaluation of the predictive acquisition system

Figure 7 shows a display example of the experimental system, which is a simulator implemented on Windows XP Professional. The terminal is moving from its current position at the center of the left-hand screen and moving downward. Based on the content acquisition zone depicted as a large ellipse, position-dependent content is searched for from the list content, acquired predictably and stored in the cache. As for content display, content relating to the position ahead is selected based on the content display zone, indicated as a small ellipse, and is presented to the user in advance on the right-hand screen.

We are at present evaluating the reducing effect of the acquisition time by this predictive acquisition system for both straight and turning movements of the terminal, of which only the former case is described in this paper. The criteria of the performance evaluation include the hit rate, indicating the ratio of predictably acquired content in the cache to that of content needed for display, the average acquisition time and the cache use efficiency, indicating the rate of number of content items used for the display compared to that of predictably acquired content in the cache. Parameters include average content size, the velocity at which the terminal is moving, and the shape and its parameters (radius for a circle, major and minor axes for an ellipse) of the content acquisition zone E_1. This paper shows the results under the conditions shown in Table 1. In this Table, content density is defined as the number of content items per 1 km^2. The content density varies for urban and suburban areas. For example, in urban areas, the density of contents targeted for acquisition is usually high, while in suburban areas, it is generally lower than in urban areas. However, for applications in which regional contents corresponding to general TV programs are acquired automatically from the cellular phone network according to the current position and displayed synchronously with the TV program, and in cases where filtering by program type and user profile is carried out, the volume of the contents targeted for acquisition decreases even in urban areas, and so does the substantial content density. This time we conducted experiments for cases where the content density was $10/km^2$ and $25/km^2$ as low and high densities respectively. The content acquisition zone E_1 was specified in three ways: as an ellipse and as a circle with size varying according to the velocity at which the terminal is moving, and as a circle of fixed size. For the ellipse, the content acquisition zone E_1 was set to be the area that would be covered if the terminal were to move from its current position for 180 seconds in the forward direction and 60 seconds in the lateral direction. (These correspond to an area of 1.5km in the forward direction and 0.5km in the lateral direction for a travel speed of 30 km/h and to an area of 2.5km in the forward direction and about 0.8km in the lateral direction for a travel speed of 50 km/h.) For the circle whose zone size varies with the velocity of the terminal, the radius was set such that the content acquisition zone had an area equal to that of the ellipse. For the fixed-size circle, the radius was set to be equal to that when the terminal speed was at 30 km/h. For these three ways, the content display zone E_2 was set to be an area covered by movement 60 seconds in the forward direction and 30 seconds laterally. (These correspond to an area of 0.5km in the forward direction and 0.25km in the lateral direction for a travel speed of 30 km/h and an area of about 0.8km in the forward direction and about 0.4km in the lateral direction for a travel speed of 50 km/h.)

Table 1: Experimental conditions

Transfer rate (bps)	38400
Content density ($/km^2$)	10, 25
Number of content items	500
Average content size (bytes)	120K
Velocity of terminal (linear, km/h)	30 - 100

As shown in the table 2 (for a content density of 25 km^2), there were no significant differences between any of the methods of specifying the acquisition zone for a travel speed of 30 km/h. However, for travel speeds of 50 and 100km/h, remarkable performance improvements were identified in all evaluation items by using an ellipse to specify the acquisition zone compared to the other two methods of specifying the zone. These experimental results can be explained as follows. When a terminal moves straight, the contents located ahead are necessary, while those in other directions (lateral and backward) are not required. However, since contents are acquired evenly in all directions, when circles are used for specifying the acquisition zone, there is a higher possibility for unnecessary contents in a lateral or backward direction to be acquired compared to cases where ellipses are used. Therefore, when circles are used, the hit rate and cache use efficiency decrease compared to cases where ellipses are used.

Next, we will consider the experimental results 2 (table 3 for a content density of $10/km^2$). In the case of 50km/h, any of the methods of specifying the acquisition zone produced a hit rate greater than 90%. Based on these results, we can assume that the terminal has been able to acquire most of the necessary contents beforehand, using either method. By succeeding in predictive acquisition, the average acquisition time was also reduced. With regards to the cache use efficiency, the performance was improved when ellipses were used to specify the acquisition zone, compared to the other two methods. In the case of 100km/h, using ellipses has yielded the highest hit rate and cache use efficiency. According to the similar consideration to that for the experimental results 1, using ellipses seems to have suppressed the acquisition of unnecessary contents. When using a circle that changes its size according to the travel speed, both the hit rate and the cache use efficiency were inferior to the fixed circle. The reason why each performance deteriorated can be explained as follows. In cases where the travel direction is not taken into account, like in a circle, the probability of acquiring unnecessary contents increases as the zone gets larger. As a result, we can assume that the cache use efficiency has decreased and the probability of acquiring necessary contents has also decreased, resulting in a low hit rate.

Subsequent to the examination of the experimental results 1 and 2, it is expected that when a terminal moves straight, and ellipses are used to specify the acquisition zone (by taking the travel speed and direction of the terminal into consideration), a high performance can be achieved.

Further, when comparing the experimental results 1 and 2, we can see that experiment 2 generally offers better performances with regards to the evaluation items including the hit rate, average acquisition time and cache use efficiency. This can be attributed to a decrease of the terminal's contents acquisition processing load due to a decrease in the volume of contents to acquire.

These results indicate that the contents acquisition performance can be improved by reducing the volume of contents to acquire through filtering by the terminal.

Table 2: Experimental results 1
(for a content density of 25/km^2)

Speed		Ellipse	Circle	Fixed
30	Hit rate [%]	100	99.3	100
	Average acquisition time [sec]	0.09	0.17	0.11
	Cache use efficiency [%]	60.9	42.8	48.5
50	Hit rate [%]	99.2	48.7	54.7
	Average acquisition time [sec]	0.18	1.5	1.4
	Cache use efficiency [%]	58.3	22.0	27.3
100	Hit rate [%]	56.4	30.8	16.7
	Average acquisition time [ms]	1.4	2.1	2.4
	Cache use efficiency [%]	32.4	17.4	8.00

Table 3: Experimental results 2
(for a content density of 10/km^2)

Speed		Ellipse	Circle	Fixed
30	Hit rate [%]	100	100	100
	Average acquisition time [sec]	0.07	0.07	0.06
	Cache use efficiency [%]	43.9	32.1	37.1
50	Hit rate [%]	100	91.5	100
	Average acquisition time [sec]	0.11	0.33	0.07
	Cache use efficiency [%]	56.9	35.8	37.1
100	Hit rate [%]	88.8	42.6	78.3
	Average acquisition time [ms]	0.46	1.7	0.69
	Cache use efficiency [%]	56.9	20.9	30.0

4. Conclusions

In this article, we have proposed a position-adaptive broadcasting system for moving objects that is capable of meeting various user requirements (change in granularity used to express position). We also considered the factors that delay the display of contents. After taking various factors into consideration, we have resolved the display delay problem by achieving a predictive content acquisition function which specifies the content acquisition zone E_1 in order to shorten the content acquisition time. In addition, we have demonstrated the effectiveness of the system quantitatively through simulations.

This system is not easily influenced by degradation of transmission quality caused by such as transmission errors in the radio network, because the mobile terminal selects content and performs predictive acquisition control. Further, it is not necessary to equip the server with special functions such as a search facility or for transmission of private information, such as the terminal's position, to the server. We are planning to conduct an experiment to evaluate the predictive acquisition system under conditions as close to the actual environment as possible, by taking the server load and the network bandwidth change into consideration. Further, we have to formulate a concrete design method for E_2 and a display control algorithm which takes into account the search time, the required content replay time and the content density. For example, we must examine a filtering system for content acquisition and display using the contents acquisition history, program type and user profile information, for cases where the volume of contents targeted for display and acquisition exceeds the processing capability of the terminal.

By resolving the above issues, we can propose a system for displaying the contents within a specified period before users pass by the position related to the content. Consequently, the purpose of this article will have been satisfied, i.e. the automatic content selection system; automatic selection, acquisition and display of content (broadcasting program).

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