Estimation of Home-address Numbers on the Basis of Relationships and Directions among House Blocks

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Abstract

To extract the address information automatically from house map images is an important subject to construct house databases which support various kinds of regional services for residents. The extraction procedure of home-address numbers can usually be implemented by the character recognition techniques. However, it is difficult for many character recognition methods to distinguish distorted or noise-overlapped home-address numbers precisely. To cope with this difficulty, we address a complementation method to infer undeterminate home-address numbers, using already established home-address numbers of neighboring house blocks. Our method first estimates the address difference among home-address numbers on the basis of house block layout pattern, and then infers the undeterminate home-address number from adjacently surrounded house blocks. We also evaluate our method through experiments.

1 Introduction

We discuss an experimental method to extract the address information from house maps in order to construct house databases. Generally, it is not easy to extract home-address numbers from house map images successfully because they are located to the corners or boundary lines of house blocks[1]. Until today, the Hough transform method[2], line-density-oriented method[3] and so on[4, 5] have been proposed as extraction methods of characters/numbers in maps, while as the digit recognition the method which composes first the decision tree from various characteristic values, and then destinguishes appropriate digit numbers according to the decision tree[6] has been reported. To recognize home-address numbers from house map images the problems that home-address numbers are distorted, located in different directions, and overlaid on other map elements, must be resolved. However, the existing methods are not always useful to cope with these problems. Moreover, the applications of only character recognition techniques are limited too strongly to the extraction abilities because the printed digits in often used house maps are sealed with human written memos and attached noises.

In this paper, we address a method to estimate un-known home-address numbers with respect to the neighboring blocks and then complement appropriate home-address numbers. In our idea, the address difference among neighboring blocks, is in advance computed and then the un-known home-address number is infered selectively from the relationships and directions among mutually related blocks[7, 8]. In this case, these relationships and

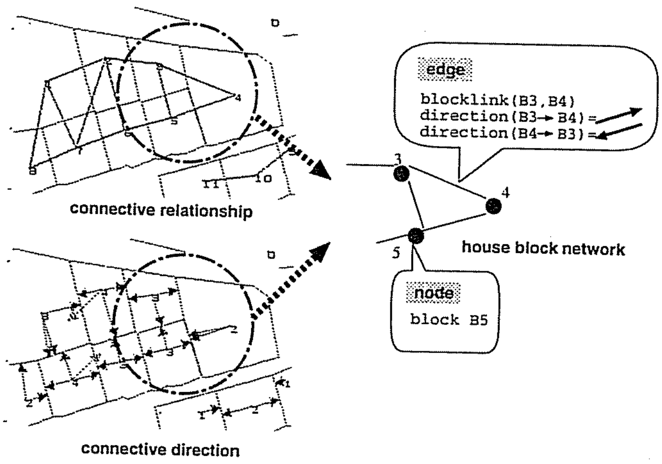

Figure 1: Distribution of address differences and house block directions

directions are derived observably from heuristics about our really sampled home-address numbers.

2 Approach

Our estimation/complementation method is organized under the process which propagates first the home-address numbers of neighboring blocks into the block of un-known home-address number, then computes the address difference among home-address numbers from a set of propagated home-address numbers, and finally estimates appropriate candidates for un-known home-address number on the basis of the address differences. We introduce the block sequence pattern (BSP) in order to estimate the address difference precisely. BSP is defined as a geometric relationship among neighboring blocks, and is also organized with respect to the connective direction. BSP is divided into several categories with depending on the number of house blocks. In order to identify BSP on the house map, we first extract the house block network as a topological configuration, and then distinguish individual BSP's on the house block network. The house block network is systematically transformed from the house map image, based on the neighboring relationship and connective direction. The nodes point out individual blocks, and the edges indicate the neighborhood, derived from neighboring relationship and connective direction. Figure 1 shows a house block network.

While, BSP is illustrated in Figure 2. BSP's depend mainly on the connective directions and are parts of house block network. The address difference is estimated for a set of home-address numbers, collected in advance from sampled house maps, and is arranged into BSP_k's (k is the number of nodes included in BSP). The average address difference and error range are assigned to BSP_k's individually: the average address difference is typically the average of all address differences; and the error range is the ratio of error for this average address difference. Table 1 shows such an average address difference and error range with respect to individual BSP_k's.

3 Estimation and Complementation

First the house block network is composed on the basis of block recognition, extraction of neighboring relationship and identification of connective direction. BSP_k's are preset analytically in advance from sample house maps. After then, using the address difference

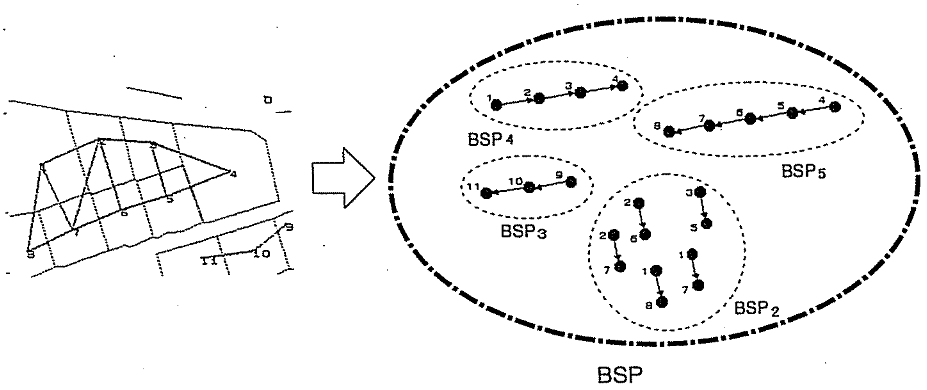

Figure 2: Example of BSP's

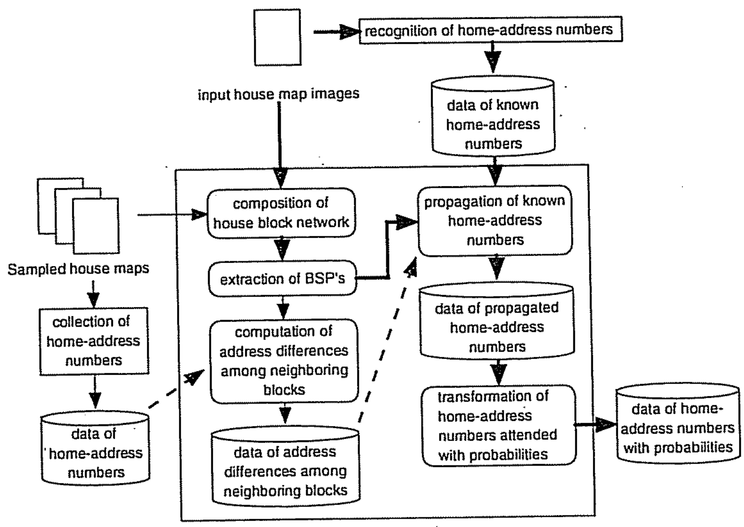

Figure 3: Processing flow in complementation

the un-known home-address numbers, associated with probability values, are estimated. Figure 3 shows the processing flow.

3.1 Extraction of House Block Network

Figure 4 shows the extraction process of house block network. The block boundaries can be extracted as continuously circled line segments of black pixels. In general, the noises attached accidentally with these block boundaries may be extracted together if the block boundaries were recognized directly from continuous line segments or black pixels. To cope with this problem we focus on continuous line segments of white pixels. Figure 5 illustrates the processing cases graphically. Namely, the house block is defined as the region whose outer surrounded area is more than a threshold value in size. The recognized blocks become nodes in the house block network.

Next, it is necessary to recognize the neighboring relationships among blocks. The line segments shared commonly between two neighboring blocks are vectorized, and become edges in the house block network. Finally, the connective direction is estimated as the direction of vertical line segment for line segment, which is shared commonly between neighboring blocks.

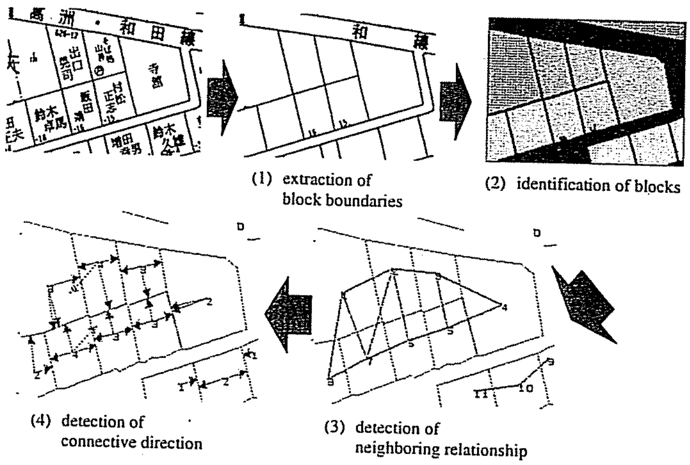

Figure 4: Extraction process of house block network

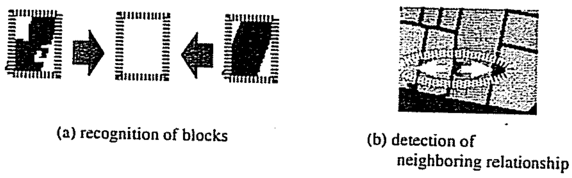

Figure 5: Robust features of white connective pixels against noises on block boundaries

3.2 Detection of Block Sequence Pattern

This process extracts the characteristic relationships from house block network in order to assign home-address numbers according to the connective direction. After then, by matching the assignment class with already preset BSP_k's the home-address number can be estimated by means of home-address numbers of matched BSP_k's.

3.3 Estimation of Address Difference

This process computes address differences in accordance with BSP_k's. First, the address differences for all neighboring blocks from sampled house maps are computed, and then the average, maximum and minimum values are calculated from a set of address differences with respect to individual BSP_k's. The average value is looked upon as the average address difference for BSP_k's. The error range is defined as the absolute largest value of difference among the average value and maximum/minimum values. Table 1 arranges the average address differences and error ranges for individual BSP_k's ($k = 1 \cdots 15$), analyzed from 878 pairs of neighboring blocks and also observed in 10 samples of house maps.

3.4 Propagation of Recognized Home-address Numbers

The propagation to the block of un-known home-address number from already preset blocks is controlled for two following conditions in accordance with the average address differences, error ranges and the existence of already preset blocks.

Table 1: Average address difference and error range

	No. of total address differences	Average address difference	Error range
BSP_2	335	5.65	14.3
BSP_3	37	3.97	16.0
BSP_4	44	1.41	12.6
BSP_5	74	1.86	10.1
BSP_6	56	0.80	6.20
BSP_7	58	1.90	18.1
BSP_8	28	2.18	17.8
BSP_9	12	0.50	3.50
BSP_{10}	13	0.85	3.15
BSP_{11}	7	0.92	4.00
BSP_{12}	22	2.33	3.67
BSP_{13}	24	2.77	17.2
BSP_{14}	77	0.81	8.19
BSP_{15}	91	0.77	3.23

[Conditions for propagation]

1. blocks of un-known home-address numbers whose average address differences and error ranges are less than the threshold values of already preset blocks.
2. blocks of un-known home-address numbers which are not followed when the path to another block from one is constructed.

The set of un-known blocks which are satisfied with the above two conditions is defined as the propagation range. This propagation process sends the clearly recognized home-address numbers to the block of un-known home-address number within the propagation range. Before the propagation, this process must also analyze block allocation patterns from house block network, compute two neighboring blocks which BSP_k belongs to, and then register the corresponding average address difference and error range into each edge. Thus, the average address difference and error range are added into home-address numbers on the propagation range, and home-address numbers are updated one by one on the propagation path. Of course, if the updated home-address numbers were not within the propagation range, the propagation process is finished. This procedure is as follows: here, B_{cur} and B_{nxt} are currently proceeded block and block to be next proceeded, respectively.

step1: Select block B_i with already preset home-address number and then $B_{cur} = B_i$. If every B_i is selected, finish.

step2: Select block B_j of un-known home-address number, related closely to B_{cur}, and then $B_{nxt} = B_j$. If there are not such B_j, goto step1.

step3: Compute propagated home-address number of B_{nxt} from that of B_{cur} (estimated home-address number is $a(B_{cur})$ and estimated error range is $p(B_{cur})$), using the following equations:

$$a(B_{nxt}) = a(B_{cur}) \pm g(B_{cur}, B_{nxt}) \quad (1)$$

$$p(B_{nxt}) = p(B_{cur}) + e(B_{cur}, B_{nxt}) \quad (2)$$

Here, $g(B_{cur}, B_{nxt})$ and $e(B_{cur}, B_{nxt})$ represent the average address difference and error range between B_{cur} and B_{nxt}, respectively. If B_{cur} is block with already preset home-address number in the equation (2), $p(B_{cur}) = 0$.

step4: If $p(B_{nxt}) < p_0$ or $|a(B_i) - a(B_{nxt})| < a_0$, then goto step1. Otherwise, $B_{cur} = B_{nxt}$ and goto step2. Here, p_0 and a_0 are threshold values.

3.5 Transformation into Home-address Number with Probability

This process transforms the propagated home-address number into a set of home-address numbers with probabilities. To make the probability at estimated home-address number maximum and also make the probability high even if the estimated error range is large and the home-address number is far from the estimated one, we compute the probability $P(x)$ for home-address number x, using the equation (3):

$$gs(x, \mu, \sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{3}$$

$$P(x) = \frac{1}{N} \sum_{n=1}^{N} \int_{x+0.5}^{x-0.5} gs(y, a_n, kp_n) dy \tag{4}$$

In the equation (4), a_n and p_n represent the estimated home-address number and estimated error range, respectively, and also k is a normalized constant. The value range of x is effective in the equation (5). Using $P_{a_{max}}$ and $P_{a_{min}}$ for a_{max} and a_{min}, the maximum a_{max} and minimum a_{min} in the set of propagated home-address numbers are:

$$a_{min} - 3kp_{a_{min}} \leq x \leq a_{max} + 3kp_{a_{max}} \tag{5}$$

Here, since x is a home-address number and is a positive integer, in case that $a_{min} - 3kp_{a_{min}} \leq 1$, x is newly defined as follows:

$$1 \leq x \leq a_{max} + 3kp_{a_{max}} \tag{6}$$

4 Experiment and Evaluation

We implemented our prototype system by C++, and evaluated our method through some experiments. Every house block network was composed from house map images of size 1/2000 by the image scanner. In addition, we input directly home-address numbers from house maps for individual nodes in the house block network, and constructed the database of home-address numbers in advance. In our experiments for complementation accuracy, we look upon the pre-constructed database as a complete database, and prepared incomplete databases by deleting some data at some ratios (20%, 40%, 60% and 80%). Using these artificially prepared incomplete databases, we applied our complementation method to such incomplete databases, and compared complemented databases with preset database.

Figure 6 is a typical example of house map: the block symbolized by "●" is assumed to be a block of un-known home-address number. This house map image is 638 × 641 pixels, scanned in 200 dpi. Figure 7 illustrates the complementation process for un-known home-address number. Also, Figure 8 shows the probability distribution for estimated home-address numbers (as the horizontal axis). This un-known home-address number is *97*, and is pointed out by the symbol "▽" in Figure 8. In Figure 7, three preset home-address numbers *71*, *97* and *98* are propagated to this block with un-known home-address number. The preset home-address numbers *97* and *98* belong to the edge of BSP_9 together, and the average address difference is *0.50* and error range is *3.50* in Table 1.

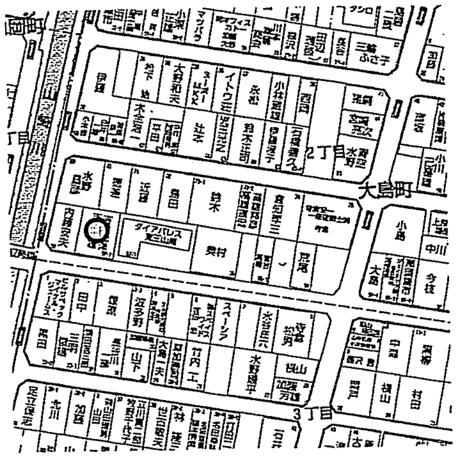

Figure 6: House map image1

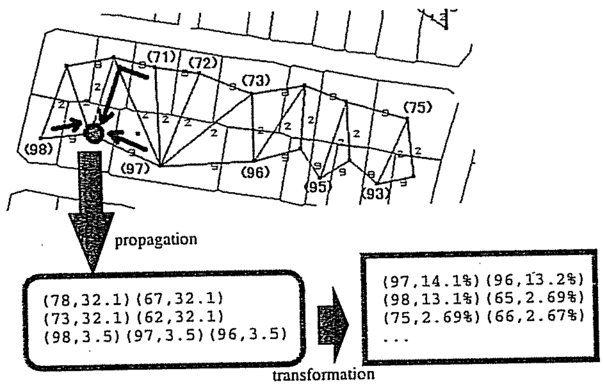

Figure 7: Example of complementation process for block ●in Fig.6

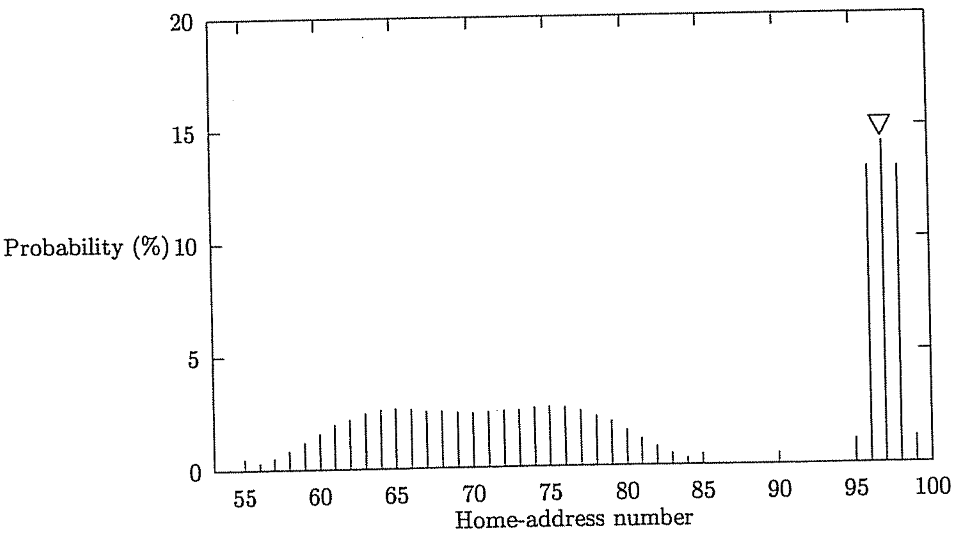

Figure 8: Output example for Fig.6

Table 2: Result of complementation process

	20%	40%	60%	80%
Known address number	303	228	153	78
Unknown address number	73	148	223	298
Average address number	26	28	29	29
Complemented blocks (1)	18	26	34	27
Complemented blocks (2)	24	40	63	51
Complemented blocks (3)	32	55	81	74
Complemented blocks (all)	66	134	197	237

Note:

20%,40%,60%,80%: Ratio of deleted home-address numbers

Known address number: No. of blocks with home-address numbers

Unknown address number: No. of blocks without home-address numbers

Average address number: No. of average home-address numbers, generated from complemented process

Complemented blocks (1,2,3,all): No. of successfully complemented blocks, by top one, two, three and all estimated home-address numbers

While, *71* belongs to both an edge of BSP_2 (whose average address difference is *5.65* and whose error range is *14.3* in Table 1) and an edge of BSP_8 (whose average address difference is *2.18* and whose error range is *17.8* in Table 1), at once. Thus, in Figure 8 the probabilities, associated with home-address numbers *97* and *98*, are higher than that of home-address number *71*. Namely, our estimation/complementation method is well applied to this case and could estimate one close to the home-address number *97* exactly.

Next, we arrange experimental results in Table 2 for 376 blocks, extracted from 10 house maps. In the deletion ratio 40 % in Table 2, 28 home-address numbers are generated in average for one un-known block. Also, the number of complementarily generated address numbers covers 93.2% (= 134/148) for all 148 un-known blocks, successfully. Additionally, we can observe that our probability manipulation works well: for example, the number of the top three successfully complemented blocks is *55* and covers 37% for all un-known blocks 148. If we did not apply our probability-based estimation method, the coverage ratio is 10% $(= 1 - (27/28)^3)$. Thus, our probability-based estimation method is superior to the simple complementation method.

Finally, we consider a failure example. Figure 9 shows another house map. The symbol "●" in Figure 9 indicates an un-known block. The complementation process is illustrated in Figure 10, and the probability distribution is shown in Figure 11. The correct home-address number for this un-known block is *47*, and is denoted by the symbol "$\bigtriangledown$" in Figure 11. In Figure 11, the peak points are close to *30*, and are far from the correct home-address number *47*. In this case, the preset home-address numbers *31* annd *44* are propagated to this un-known block, but in Figure 10 *31* and *44* belong together to BSP_7 and BSP_8. Although the address difference between un-known block and block *31* is 31, as the distribution of BSP there are either two edges in BSP_7; or two edges in BSP_7 and one edge in BSP_8. Thus, the transformed address difference on the basis of these consideration is 3.8-5.0 and this value derives the failure. In Figure 9, the un-known block is composed as rectangular blocks and our BSP is not always effective to estimate accurately the address difference. We need to apply other means to such rectangular blocks, or to use other characteristic features.

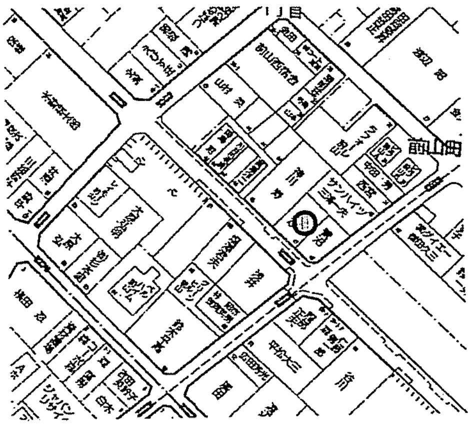

Figure 9: House map image2

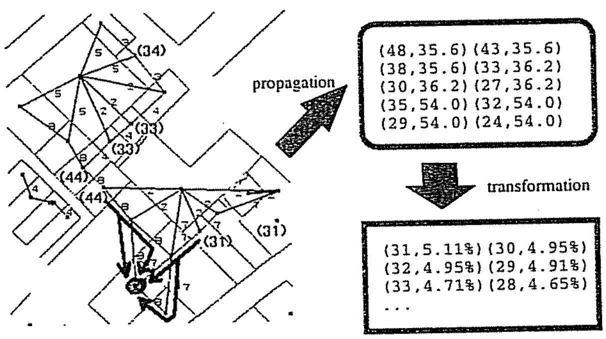

Figure 10: Example of complementation process for block ●in Fig.9

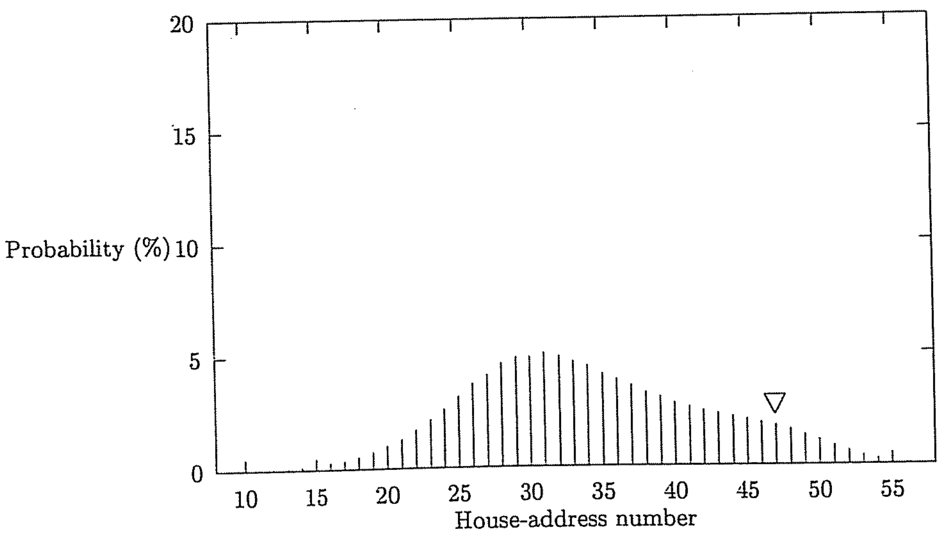

Figure 11: Output example for Fig.9

5 Conclusion

In this paper, we discussed an estimation/complementation method to infer the un-known home-address number, using the neighboring relationship and connective direction. Our method is to make use of characteristic features: the average address difference and error range, derived from BSP_k's, which are topological relationships among related blocks on the house block network. Also, we introduced the probability to select candidates of home-address numbers. This probability-based approach is very superior to the traditional approaches: our experiment makes this clear. Of course, our method was very effective and successful through some experiments.

As our future work, we must investigate the following subjects: 1) improvement of BSP_k's for making its complementation accuracy high; and 2) development of new method in case that some errors are included in preset home-address numbers.

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