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ANALYSIS OF SCALE AND DISTRIBUTION CHARACTERISTICS OF SHELTERED HOUSING IN THE UK AND THE ENLIGHTENMENT TO CHINA

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Abstract. *Sheltered housing is a popular living form designed for the elderly in the UK. By simulating and predicting some indicators of sheltered housing, we can draw on the experience of the UK to help improve the pension system in China. First, sheltered housing is introduced in four aspects including the origin and development, the architectural features, the characteristics of scale and the characteristics of location and we also clarify the purpose of the paper in the introduction section. Second, the basic theory of support vector machine is presented. Third, we predict with SVM and PCA several indicators, such as distances from downtown, built cities and quantities of rooms. Finally, we arrive at the conclusion that SVM is more suitable for predicting the scale and location of sheltered housing.*

Keywords: Sheltered housing, Chinese pension, Support vector machine, Prediction

1. **Introduction.** Sheltered housing, a collective living form equipped with resident wardens, is originated from the United Kingdom and specially designed for the elderly [1]. Since it was first proposed in the 1960s, it has been regarded as the best form that can satisfy the living need of the elderly by more and more pension professionals and policy makers [2]. This kind of living form is not only an intermediate one between rental housing and self-owned housing, but also a transitional one between independent housing and institutional care. A recent survey shows that people in the UK prefer to live in the sheltered housing rather than in their own homes when they become old [3].

Sheltered housing is mainly built in the form of multi-storey apartments. It is equipped with resident wardens and emergency call systems for the elderly, which differentiates it from the common apartments. To some extent, it is enough for the elderly who can live on their own to enjoy the service above. Different from the nursing home, there will not be many nurses and medical care facilities equipped for the healthy elderly people in the sheltered housing. Also, resident wardens will not interfere in the life of the elderly unless asked to help, which leads to small demands for wardens. Meanwhile, the operating cost is kept low due to the limited facility cost and human cost, which makes it a cheap living option for the elderly and for those who are healthy but can hardly afford the high expenses of living in the nursing home. More importantly, sheltered housing is mainly run in the form of rental, not for sale. Thus, the elderly just need to pay the rent instead of a large purchase cost.

1.1. **The origin and development.** Sheltered housing is a living mode for the elderly originated from the United Kingdom in the 1960s, aiming to improve the life quality of the elderly [4]. It is mostly for rent, and not for sale.

During the midterm development, there existed some doubts on this kind of living form, focusing on whether it can satisfy the demands for the elderly well, whether it is a perfect mode, how the elderly can better transit to other pension stages from sheltered housing and so on [5].

In the beginning, sheltered housing was developed and operated mainly by the government. In the late 20th century, developers began to interfere in the construction of sheltered housing, while the government gradually turned into the role of policy makers, that is to say, the government is responsible for making the plan, including the size and layout, and developers are in charge of construction and operation. The interference of commercial development brought rapid development of sheltered housing. Now, there is the largest amount of sheltered housing in the United Kingdom in the world and the construction of sheltered housing in every city is comparatively perfect.

Following the United Kingdom, many European and North American countries have begun to take action to reduce the construction of nursing homes, and at the same time, increase the construction of sheltered housing.

1.2. **The architectural features.** Sheltered housing is generally built in the community and adjacent to other infrastructures in order to facilitate the elderly [6]. It is usually made up of a number of independent living units, each of which consists of an apartment for the elderly and a public living room. Each elderly man has his/her own apartment and a few apartments share a public living space. The public living room provides social space for the elderly and the space to share the service of the apartment. The individual apartment for the elderly is often small, generally 30-40 square meters in area, while the public living room will occupy more space in order to encourage the elderly to interact with each other and thus to reduce the possibility of loneliness.

1.3. **The characteristics of scale.** As is shown in Table 1, we use the number of rooms in each apartment as an indicator of the scale data of sheltered housing in several British cities. Here, we take 10 rooms as an interval to conduct the statistics. The following conclusions can be obtained from the table. In the United Kingdom, most of sheltered housing has less than 50 rooms. Whether in the big cities like London, the medium-sized cities like Sheffield, or the small cities like Oxford, there appears to be a consistency in the scale and proportion of sheltered housing. As the total population of London is much larger than that of other cities, the number of affordable apartments for the elderly in London is also significantly larger than those of other cities.

1.4. **The characteristics of location.** As is shown in Table 2, we use the distances between the location and the city center as an indicator of location data of sheltered housing in several British cities and the following conclusions are obtained. The majority of affordable elderly apartments are located in the area within 5 miles from the city center and distributed most intensively within 2 to 3 miles from the city center. Due to the large area, the affordable sheltered housing in London is distributed in wider range. However, it can be seen that most of sheltered housing is still located in the area within 10 miles from the city center.

According to the characteristics of the data, we can conclude that sheltered housing is mainly built relatively near to the city center and in the community, which contributes to

Table 1. Statistics on the scale of sheltered housing in British cities

Number of Apartment Rooms	London	Birmingham	Sheffield	Leicester	Nottingham	Newcastle	Oxford	Brighton
1-10	178	38	12	14	16	13	3	11
11-20	353	45	20	9	15	13	8	20
21-30	492	81	16	25	53	30	20	19
31-40	445	115	30	10	40	32	9	15
41-50	492	55	9	2	7	11	3	10
51-60	75	20	3	1	5	2	4	8
61-70	50	10	1	0	3	0	0	0
71-80	23	11	1	1	1	3	0	2
81-90	12	1	0	0	5	1	0	1
91-100	5	2	0	1	1	1	1	0
101-110	3	0	0	0	0	1	0	1
111-120	1	1	0	0	0	1	0	0
121-130	0	0	0	0	0	0	0	0
131-140	1	0	0	0	0	0	0	0
141-150	3	0	0	0	0	0	0	0
151-160	3	0	0	0	0	0	0	0
161-170	2	0	0	0	0	0	0	0
171-180	0	0	0	0	0	0	0	0
181-190	2	0	0	0	0	0	0	0
191-200	0	0	0	0	0	0	0	0
200+	5	0	0	0	0	0	0	0

Table 2. Statistics on the location of sheltered housing in British cities

Distances from the City Center	London	Birmingham	Sheffield	Leicester	Nottingham	Newcastle	Oxford	Brighton
1	92	47	14	8	9	8	8	23
2	82	46	19	21	39	20	7	24
3	108	38	15	18	22	32	15	14
4	126	50	9	6	23	16	11	11
5	114	62	9	2	29	6	1	4
6	153	39	3	0	6	6	0	2
7	144	14	7	0	1	0	0	0
8	138	9	1	0	0	1	0	0
9	109	10	1	0	0	1	0	0
10	146	2	2	0	0	0	0	0
11	133	0	0	0	0	0	0	0
12	82	0	0	0	0	0	0	0
13	70	0	0	0	0	0	0	0
14	68	0	0	0	0	0	0	0
15	39	1	0	0	0	0	0	0
16	31	0	0	0	0	0	0	0
17	9	0	0	0	0	0	0	0
18	8	0	0	0	1	0	0	0
19	3	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
30	3	0	0	0	1	0	0	0

the pension living system consisting of ordinary residential, sheltered housing and pension institutions. Such a complete system existing in the community can ensure the elderly to live in their familiar environment to the greatest extent and they do not need to be forced to leave their own communities because of physical problems or other reasons.

1.5. **The purpose of the paper.** At present, China is in the stage of aging. The elderly are confronted with huge economic pressure on the pension, and in the meantime, the society is faced with the pressure from the lack of public pension resources. China has already entered the stage of aging before it can reach the same economic level as western countries at the same stage. Most of the elderly still cannot afford the expensive pension expenditures. Also, due to the limited nursing homes constructed by the government, we can only provide the housing resources for those who need medical care badly. In China, most elderly people who can live on their own are urgent to find a more economical way to spend their remaining years.

First, healthy elderly people prefer to live in their own community instead of moving out. Second, they do not need too many medical facilities because they are in good condition. Third, they hope that they can turn to live in the nursing home with professional medical conditions when their health condition is in decline in the future.

As we can see, sheltered housing is a living form, which can not only ensure that the elderly do not need to move out from their own communities, but also can reduce the risk of living, and has already been shown to be the most economical pension facility. It is not like the nursing homes that are small in amounts and centralized. It is often built in the community and next to other residences. Thus, the elderly will not move away from their own communities after moving into the sheltered housing, that is to say, they can still live in the familiar environment just like before. The warden service and emergency call service provided in the sheltered housing also ensure the living safety of the elderly. In the sheltered housing, wardens are just responsible for helping the elderly deal with the difficulties in life, and they will not be involved in organizing and managing the life of the elderly. The living units of the elderly, like the ordinary apartments, are independent and do not affect each other. Compared with the medical care institutions like nursing homes, the elderly in the sheltered housing have more freedom and private time. Therefore, sheltered housing can keep the life of the elderly independent and private to the greatest extent, which allows the elderly to live a more dignified life.

In this case, sheltered housing can be regarded as the best way to alleviate the contradiction between the rising number of the elderly and pressure from pension expenditures in contemporary China, which is sure to greatly contribute to the improvement of Chinese pension system. To provide references for the construction of sheltered housing in China, we try to predict its construction scale and construction location according to the experience of the UK. In reality, it is hard to build a reasonable model for the prediction of construction scale and construction location by human analysis, which leads us to resort to some of data-driven methods. In this paper, we will compare the results of two popular data-driven methods [7] and select the better one to conduct the prediction work.

2. **Introduction of SVM.** Support vector machine (SVM) was proposed by Vapnik in 1982 [8]. It has both strong theoretical basis and decent practicability. SVM is based on the structural risk minimization principle [9] and statistical learning theory, and has been applied in industrial fault diagnosis, biological information dispose and text classification. In order to improve the classification accuracy of SVM, many methods [10, 11, 12] were proposed in recent years and many researchers have made contributions to the development of SVM [13, 14, 15, 16, 17].

SVM can be regarded as a binary classifier. The training data $\{x_1 \dots x_n\}$ are in the space $\chi \subseteq R^d$. Their labels can be represented as $\{y_1 \dots y_n\}$ and $y_i \in \{-1, 1\}$. Hyperplane is employed in SVM to separate the training data of different labels with the maximum margin. The training data on one side of the hyperplane are labeled 1, and those on the other side are labeled -1. The support vectors are the ones located the closest to the hyperplanes. Kernel functions are usually employed in SVM to map the training data into a higher dimensional feature space F in order to classify the non-linearly separable input data. All the kernel functions must satisfy the Mercer conditions. The classifier can be represented as

$$f(x) = \left(\sum_{i=1}^{n} \alpha_i K(x_i, x) \right) \tag{1}$$

where α_i represents the Lagrange multiplier, and $K(\cdot)$ represents the kernel function.

Since kernel functions satisfy the Mercer condition, they can be represented as $K(u, v) = \Phi(u) \cdot \Phi(v)$, where $\Phi(\cdot)$ represents the mapping from X space to F space. $f(x)$ can be transformed into

$$f(x) = w \cdot \Phi(x) \tag{2}$$

where $w = \sum_{i=1}^{n} \alpha_i \Phi(x_i)$, α_i can be obtained by SVM and the maximum hyperplane can be obtained in F space. It should be noticed that different kernel functions should be applied in different issues, which will generate different results. Thus, it is very important to select an appropriate kernel function.

In Table 3 we introduce some frequently-used kernel functions.

Table 3. Examples of kernel functions

Kernel Functions	Formula
Linear	$K(x_i, y_i) = x_i \cdot x_j$
Polynomial	$K(x_i, y_i) = (\gamma x_i \cdot x_j + r)^d$, $\gamma > 0$
Radian Basis Function	$K(x_i, y_i) = \exp\left(-\gamma \lVert x_i - x_j \rVert^2\right)$, $\gamma > 0$
Sigmoid	$K(x_i, y_i) = \tanh(\gamma x_i \cdot x_j + r)$

In the table, $\lVert\cdot\rVert$ represents the 2-norm, d represents the degree of the polynomial, and γ and r are two parameters used to change the distribution of kernel functions.

3. **Experiment.** In the experiment, we use SVM and PCA respectively to predict the construction scale and construction location of sheltered housing. In order to choose an appropriate prediction method, we further compare and analyze the prediction results. The experimental data include British retirement homes and sheltered housing's built cities, distances from downtown, built years and number of rooms. Three of them are treated as the input variables and the remaining one acts as the output target in each training, which means that we aim to establish a regression model between the input and the output by using SVM and PCA methods. If the regression model is accurate enough, we will adopt it in prediction.

There are totally 2776 groups of data. Different cities have different labels in the simulation pictures, which are presented in Table 4.

First, data are preproccessed and data with missing information are deleted and finally about 2000 groups of data can be applied.

TABLE 4. Different cities' labels

City	Label
London	1
Birmingham	2
Sheffield	3
Leicester	4
Nottingham	5
Newcastle	6
Oxford	7
Brighton	8

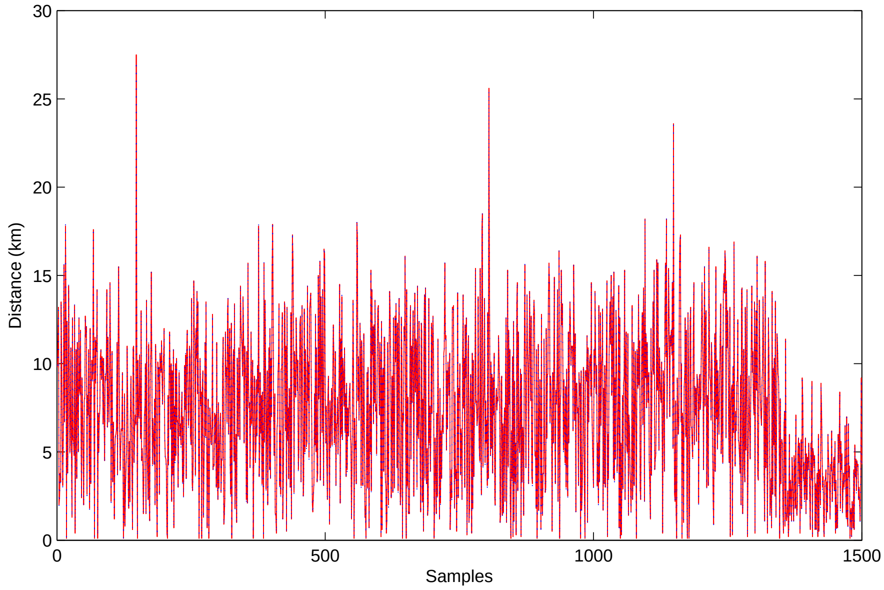

FIGURE 1. Distances from downtown in the training data

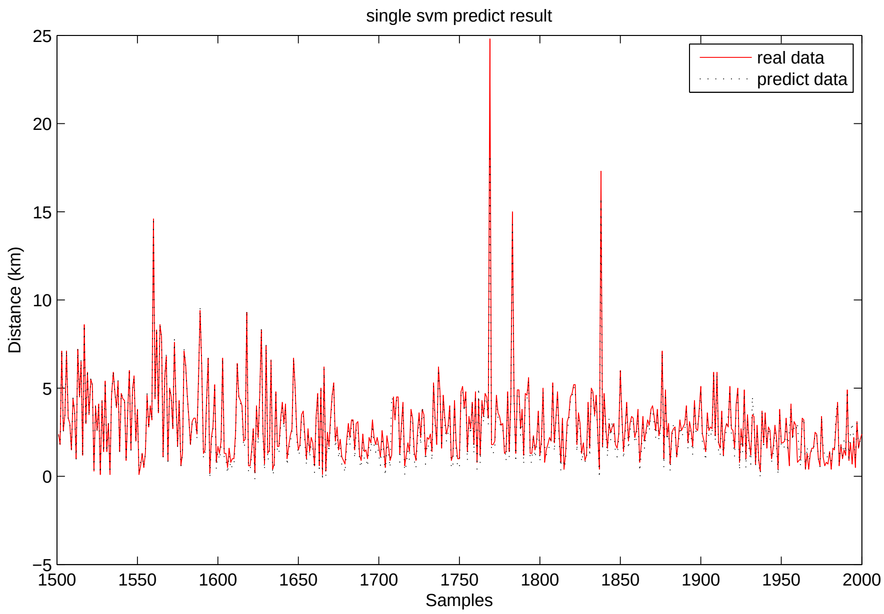

FIGURE 2. Predicted distances from downtown of the test data by using SVM

3.1. **Predicting distances from downtown.** There are totally 2000 groups of data including 1500 groups of training data and 500 groups of test data. Figure 1 shows the distances from downtown in the training data.

Figure 2 and Figure 3 show the predicted distances from downtown of the test data by using SVM and PCA respectively.

Figure 4 and Figure 5 show the errors between predicted values and real values with SVM and PCA respectively.

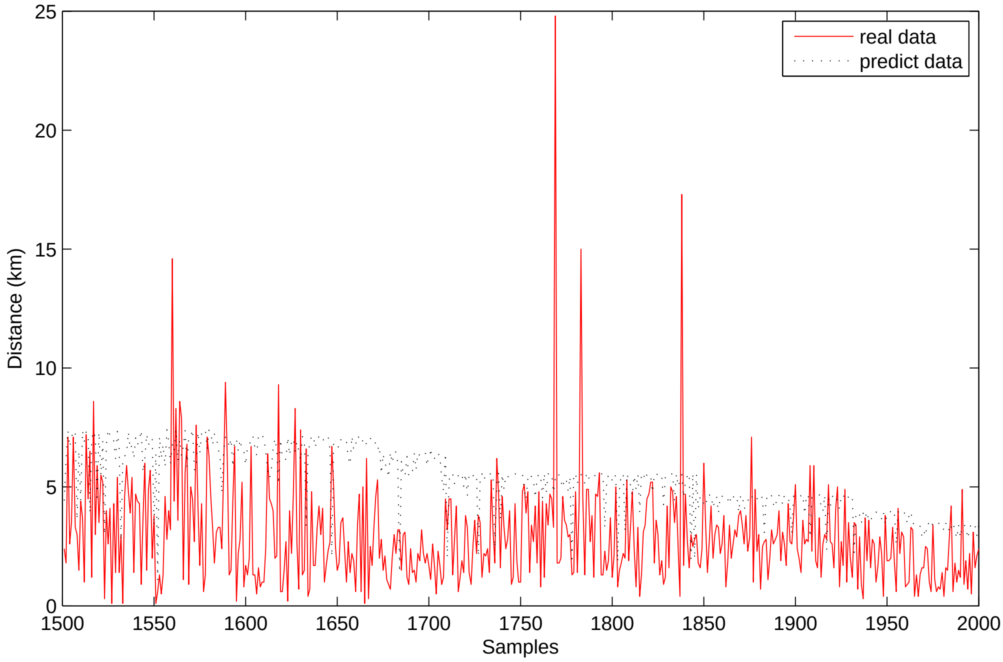

FIGURE 3. Predicted distances from downtown of the test data by using PCA

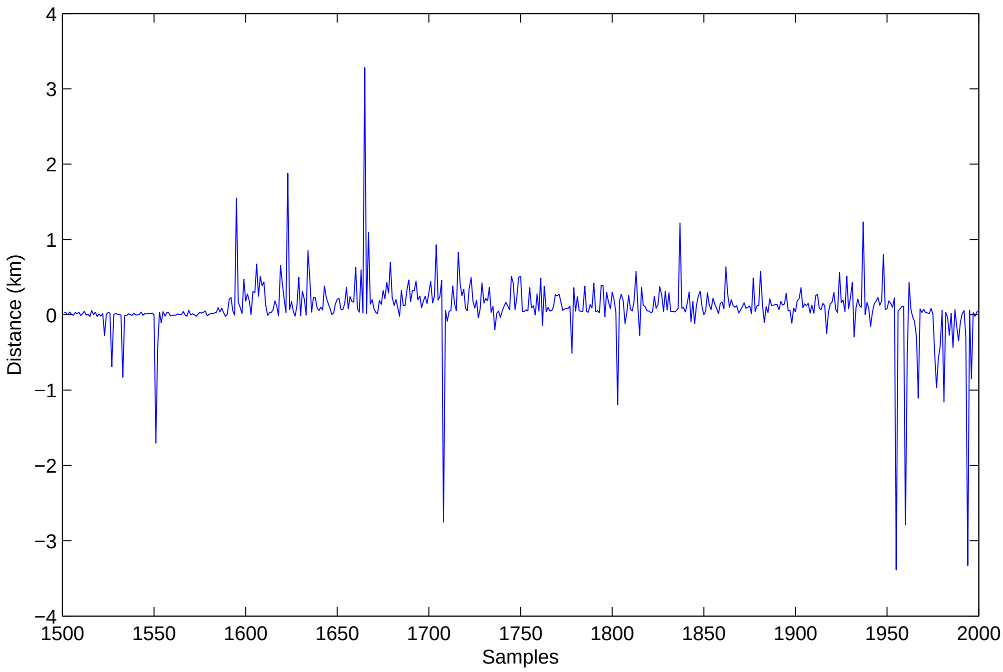

FIGURE 4. The errors between predicted distances and real ones by using SVM

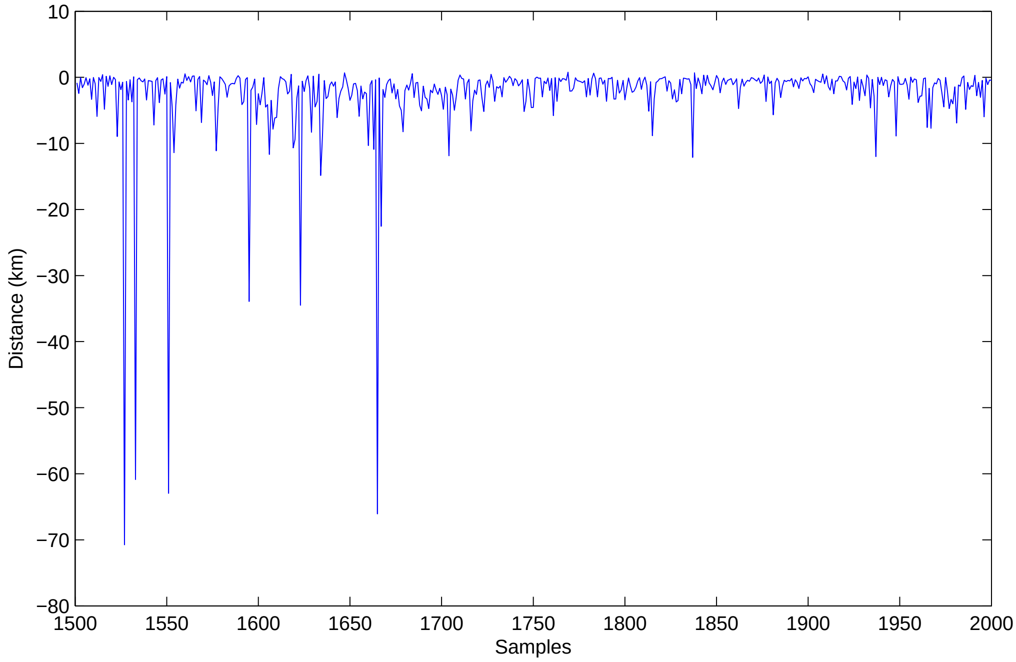

FIGURE 5. The errors between predicted distances and real ones by using PCA

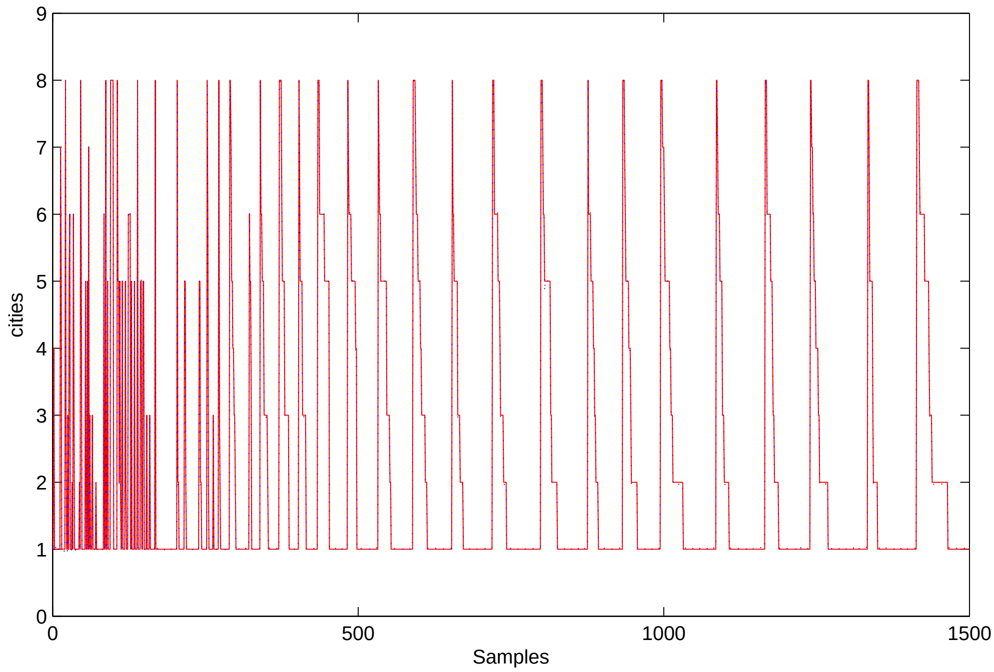

FIGURE 6. Built cities of the training data

From the simulation results, almost all of the errors in SVM prediction are between 1 and -1 km, whereas the errors in PCA prediction range from 10 to 80 km. Therefore, in this case the SVM prediction results are the better.

3.2. **Predicting built cities.** Again we have 1500 groups of training data and 500 groups of predicted data. Figure 6 shows the built cities of the training data.

Figure 7 and Figure 8 show the predicted built cities by using SVM and PCA respectively.

Figure 9 and Figure 10 show the errors between the predicted built cities and real values by using SVM and PCA respectively.

From the simulation results, almost all of the errors in SVM prediction are between 0.3 and -0.5 city, which means that almost all the predict data are accurate. Therefore, the

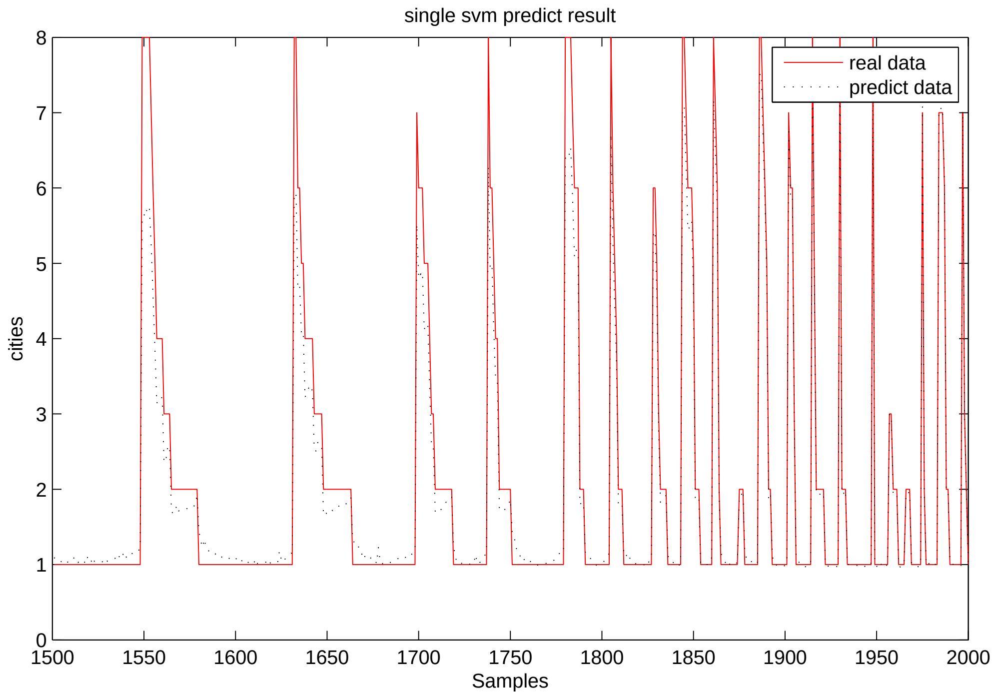

Figure 7. Predicted built cities by using SVM

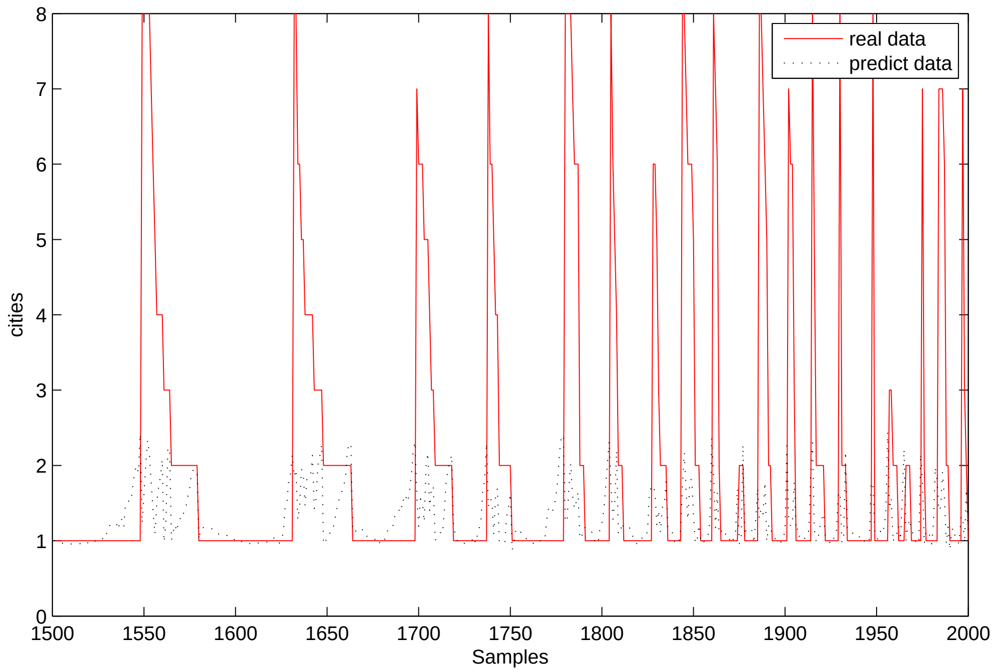

Figure 8. Predicted built cities by using PCA

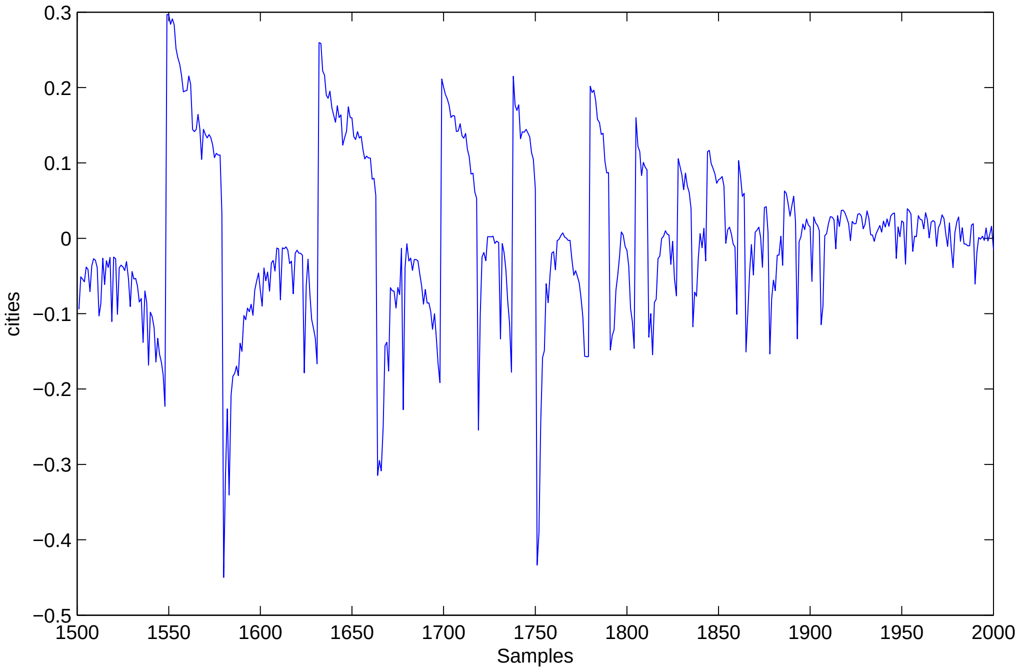

FIGURE 9. The errors between predicted built cities and real ones by using SVM

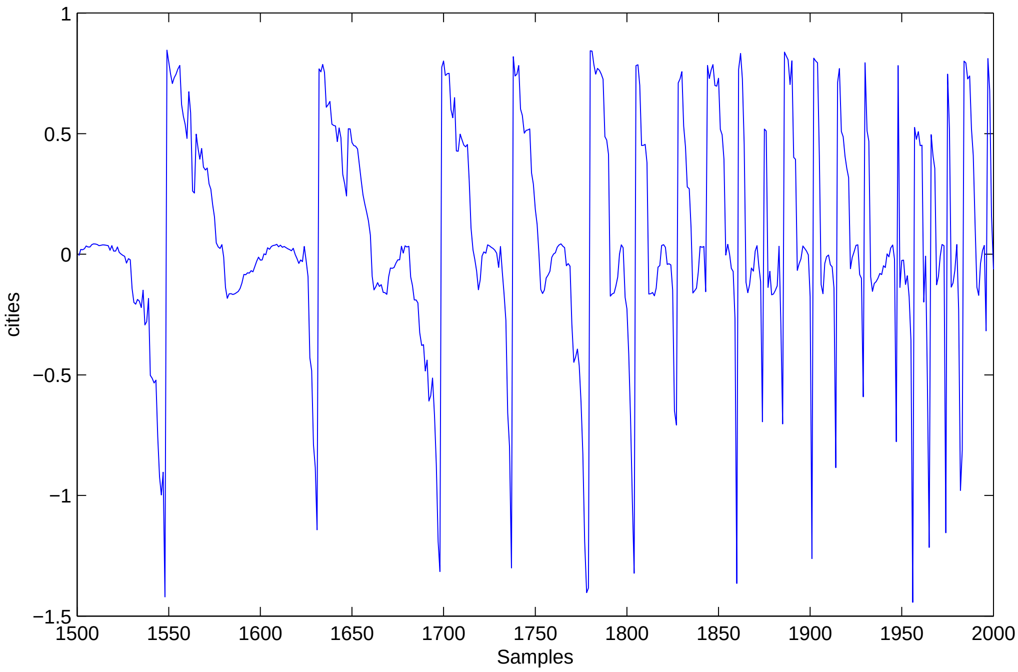

FIGURE 10. The errors between predicted built cities and real ones by using PCA

prediction results are pretty good. However, the errors in PCA prediction are between 1 and -1.5 cities, which are obviously bigger than those of SVM prediction.

3.3. **Predicting quantities of rooms.** The experimental setup of this case is exactly the same as in the former two cases. Figure 11 shows the quantities of rooms of the training data.

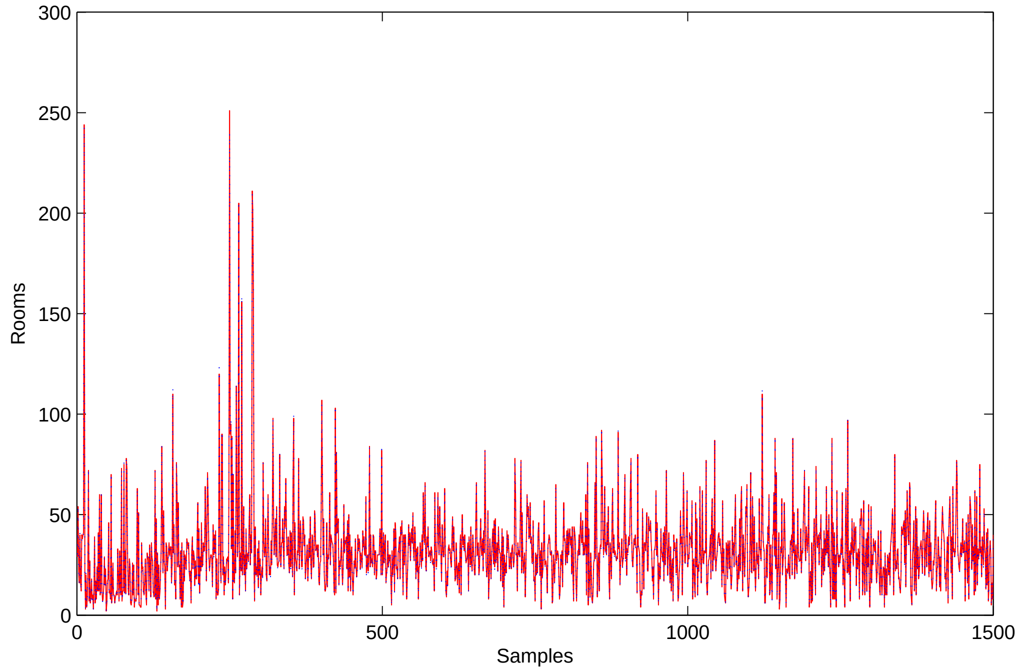

FIGURE 11. Quantities of rooms of the training data

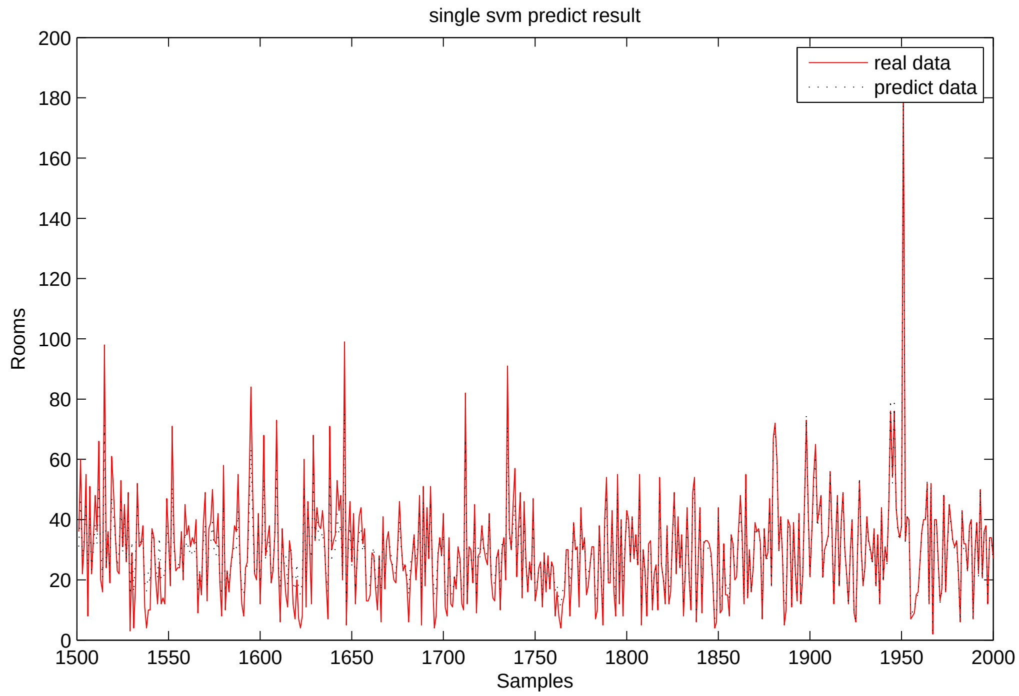

FIGURE 12. Predicted quantities of rooms by using SVM

Figure 12 and Figure 13 show the predicted quantities of rooms by using SVM and PCA respectively.

Figure 14 and Figure 15 show the errors between predicted quantities of rooms and real values by using SVM and PCA respectively.

From the simulation results, almost all of the errors in SVM prediction are between 0.5 and -1 room, which means quite high prediction accuracy. However, the errors in PCA

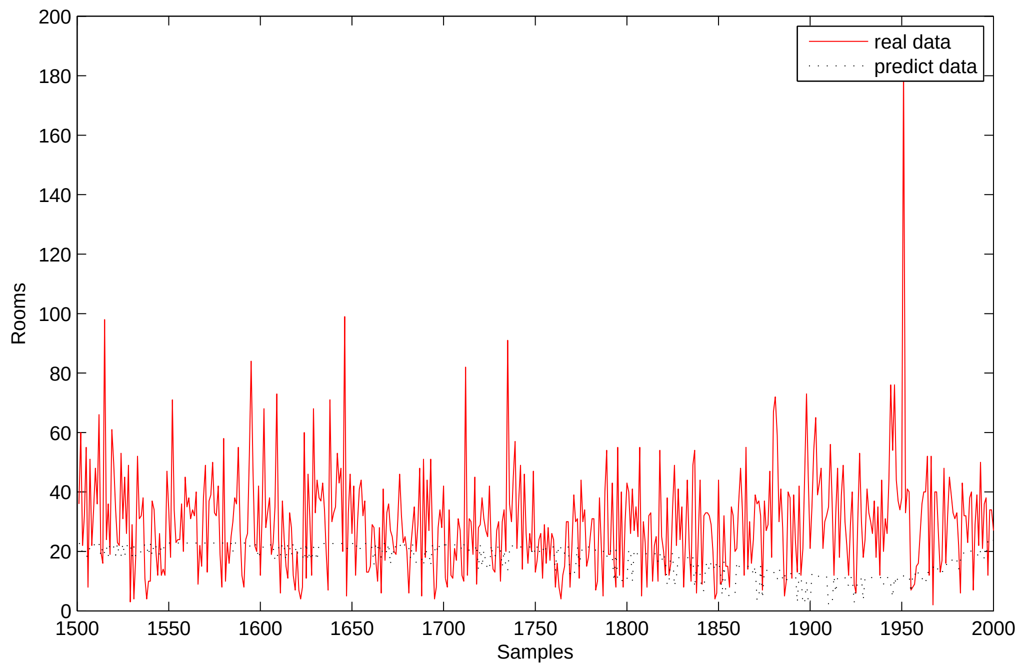

Figure 13. Predicted quantities of rooms by using PCA

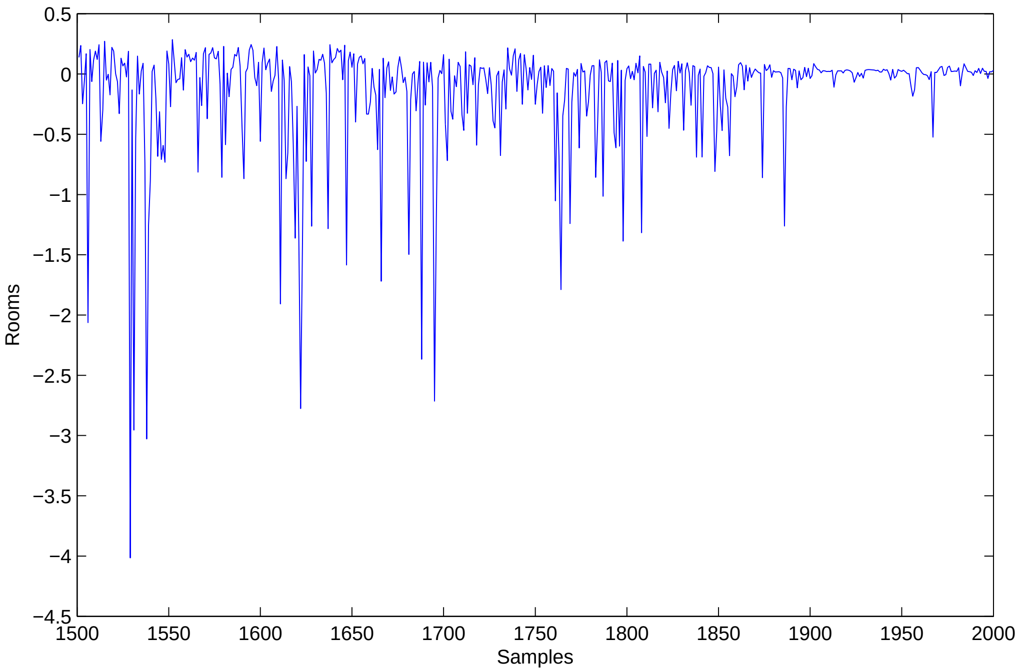

Figure 14. The errors between predicted quantities of rooms and real ones by using SVM

prediction are between 1 and −7 rooms, which implies the worse performance compared with the SVM prediction.

4. **Conclusions.** In this paper, we investigate the correlation between the construction time, the scale data and the location data of sheltered house. As a result, we arrive at the conclusion that we can predict the distances from downtown, built cities and quantities of

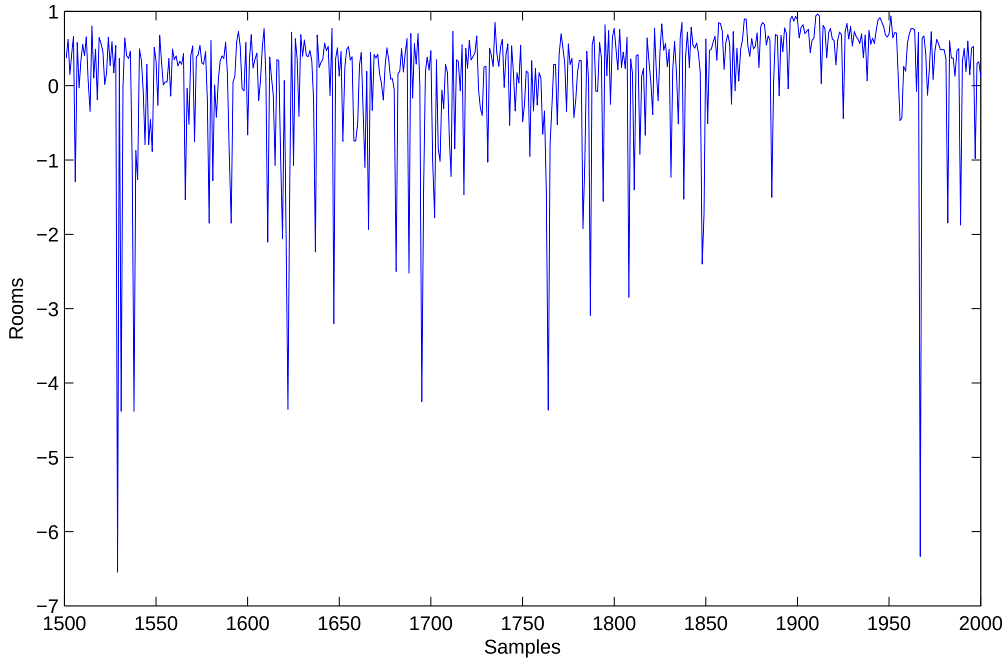

FIGURE 15. The errors between predicted quantities of rooms and real ones by using PCA

rooms by using data-driven methods based on other known indicators of sheltered housing. Furthermore, the SVM approach is more suitable for prediction compared with the PCA approach. In the future, the experience of the United Kingdom in the planning and layout of sheltered housing can be used for references in China. In view of the characteristics of Chinese cities, we can draw on this conclusion to predict the scale and location of sheltered housing suitable for the urban pension demands.

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