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# Application of Artificial Intelligence and Visualization Technology in Construction Risk Prediction

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**Abstract.** Artificial intelligence and visualization is a trend in the practical application of computers and in the research of project risk prediction methods. Although the unity, uncertainty, poor regularity and the one-time characteristic lead few applications of artificial intelligence in the field at present, yet the phenomenon of excessive investment and serious loss resulted from prediction errors make that the scientific methods to solve them are urgent. Based on the features mentioned above, traditional decision-making and forecast has a strong prevalence of subjectivity and big deviation. While the CBR of the artificial intelligence, as a scientific method referred to historical experiences, makes use of the existing data to provide the basis for decision-making and prediction by optimizing the search database to find a similar case. Based on this, this article will introduce intelligent algorithm CBR to the risk prediction step using CBR's storage and search capabilities to find out the similar cases with the project to be built on key attributes, and make those completed projects' risk data and solutions as a basis for decision making so as to uncover potential risks more objectively and comprehensively and learn from past experience measures to give preventive strategies. Meanwhile, the 3D-WebGIS technology can not only intuitively display the predictions and solutions, but also provide the functions to search and timely release information.

**Keywords:** CBR; artificial intelligence; WebGIS; risk prediction

## 1. Introduction

Artificial intelligence is a cross-scientific ideological combined computer science, logic with cognitive science. Although it emerged in 1940s, now it is still the forefront of modern computer technology. It was first used in the field of electronic control. After four stages of development, currently it has already been widely used in problem solving, logical reasoning and theorem proving, natural language processing, intelligent information retrieval, expert system and so on. Intelligence has always been a trend of scientific research, not only for computer also for other areas. In the current project risk management, although construction industry has been developing rapidly, most predictions and decisions are still in the disordered state. Especially because risk predictions in project prophase were so unscientific that the follow-up work of project could not be ensured which leads to many serious investment out of control appeared

The reasons which caused disordered project management are mainly as follows.

(1) Unique and one-time of each project;

(2) Many uncertainties in construction domain, and decisions mainly relying on subjective judgments;

(3) Information overload and people's capacity to understand and predict the future development and change is limited;

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(4) Unscientific traditional methods. Based on that, it is imminent to introduce artificial intelligence to scientific prediction and decision-making in construction domain.

Combined project management status with the defaults of existing methods, this paper proposed a new risk identification and prediction method which can analyze existing project cases. Meanwhile, this paper also introduced 3D-WebGIS as a visualization and analysis tool, in order to make predictions objective, accurate and clear.

## 2. CBR and 3D-Webgis

Case-based reasoning is a reasoning model solution by accessing the solutions of similar problems in the past in knowledge base to get the current issue resolutions, namely, making use of old cases or experiences to solve new problems, evaluate new problems and explain unusual circumstances or understand the new situations. CBR technology that solves the problems that the knowledge expresses hard by directly using the previous examples and it self-learning function ensures the continued enhancement of capability. It is an important tool efficiently dealing with similar projects[1]. This mathematical model based on the experience is closer to the most primitive way of thinking and solving problems, which not only eases the bottleneck of knowledge acquisition in conventional knowledge systems, but also has the capability of active learning and incremental learning and can deal with qualitative as well as quantitative data, so it is the most effective way of transforming project experience into knowledge. When the mechanism model, determination rules or statistical models can't access to, making use of historical similarity to solve problems has become a research focus in artificial intelligence field.

3D-WebGIS is a revolutionary new technology combined Geographic Information System technology with Internet technology. It can seamlessly integrate a series of digital map-based application services by way of three-dimensional Virtual simulation. 3D-WebGIS using a new human Web interface and the main direction of GIS development is that application systems based on three-dimensional maps, graphics or images can be widely used in various walks of life through internet technology.

As the project parameters are difficult to quantify and many uncertainties existed in practice, actual projects cannot be accurately described by single or multiple mathematical models. Especially scientific methods yet can't get scientific conclusions. Therefore, we should transform a kind of thinking. It is more effective to use CBR summarizing existing experience rather than use the theoretical formula. Meanwhile, 3D-WebGIS can provide intuitive predictions.

## 3. Key Technology of CBR

The core idea of CBR is to make use of similar successful cases to analogy reasoning[2], so the key lies in judging the similarity among buildings in the field of architecture, namely, making assumption as a precondition that the similarity is higher, the probability of risk to suffer is higher. The algorithms of calculating similarity are not unique, and this paper proposes an algorithm for calculating similarity, based on variable fuzzy formula and nearest neighbor algorithm[3], whose main idea is to split the building into a number of attributes and weigh each one, then calculate the properties difference degree. The smaller of the difference degree, the higher of the similarity. The whole prediction process of CBR is as following and it also can be seen from Fig.1:

(1) The expression of cases. In the model of CBR, the case is the basic unit of knowledge. The representation of the cases is to make structural processing and store them in case database so as to suit themselves to computer processing. Full case representation includes the descriptions of case characteristics and the establishment of a database, focusing on how to extract the key features property to reflect all the information of the project as possible.

In construction domain, the building features should be splited into a number of key attributes. And the key property is divided into controlled properties and comparison properties. properties difficult to be quantified the properties are classified as controlled properties, such as the main structure, foundation types. Only the controlled properties exactly the same, two buildings can compare attributes. Property which can be quantified are classified as comparison properties, such as project cost, the total higher buildings. On the promise of the same controlled properties, the smaller the difference of a property as a whole, the more similar between the buildings.

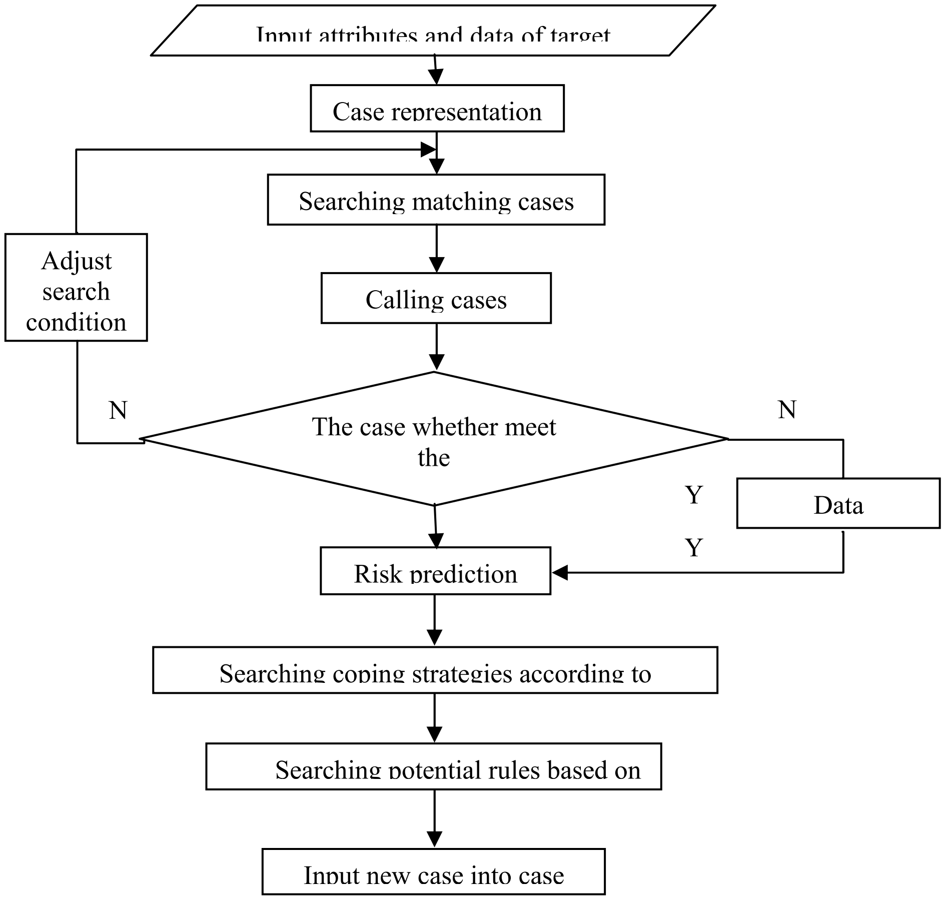


Figure 1. The whole prediction process of CBR

(2) The search of cases. As the basic principle of case-based reasoning is to find similar cases with the goal case in the case library and make use of existing case experience to provide solutions for the target case, the search is core element in case-based reasoning and its efficiency will directly affect the matching degree of search results and the accuracy of predicted results. The most commonly used search strategies are mainly nearest neighbor method, inductive indexing method and the knowledge-guided method[4]. The process is mainly related to weight determining of attributes and similarity calculation.

a. Determining weights of comparison properties should be according to their influencing degree to similarity of building. There are many weight calculation methods, such as experts discussion, AHP, etc. But the most undesirable effect of such traditional methods is coordinating difficult. So this paper used improved AHP based on possibility-satisfiability degree to balance the contradiction between the matrix compatibility and results reliability, in order to get minimum deviation results by least times of iterative.

Supposed there are n evaluation indexes of some problem, and the indexes are represented by $X=\{X_1, X_2, \cdots\cdots, X_n\}$. There are m experts score, and $\lambda$ is weight of each expert. In the group decision I(n, m, $\lambda$), supposed k is iteration number, $\overline{S.I.}$ is index critical value of compatibility. The steps of determining weights based on improved AHP are as following:

1) Supposed k=0 and $A^{L(k)}=(a_{ij}^{L})$, we do consistency check for initial matrix. If CR<0.1, then directly to step 2, or else modifying matrix which is not meet the consistency test [5][6].

2) Using programming problem as following,

$$\min F(\omega)=\sum_{L=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n}\psi_{L} a_{ij}^{L}\frac{\omega_j}{\omega_i},$$

$$\sum_{i=1}^{n}\omega_i = 1,\quad \omega_i \succ 0,\ i=1,2,\ldots,n,$$

and $\psi_L = \frac{\lambda_L}{n(n-1)-m_A^L}$ , we can obtain uniquesolution, that is complex priority $\omega^{(k)}$ And calculating the compatibility index $SI(n,m,\lambda)^{(k)} = \sum_{L=1}^{m}\lambda_L SI(A^L, W)$ .

3) If $SI(n,m,\lambda)^{(k)} \le \overline{S.I.}$ , then it can be directly to step 7, or else to the next step.

4) Calculating deviation matrix of each expert $E^{L(k)} = (\varepsilon_{ij}^{L(k)})$ , in which $(\varepsilon_{ij}^{L(k)}) = a_{ij}^{L(k)}\frac{\omega_j^{(k)}}{\omega_i^{(k)}}$ . Supposed $\varepsilon_{st}^{r(k)} = \max(\varepsilon_{ij}^{L(k)})$ and $\overline{E^{L(k)}} = \overline{(\varepsilon_{ij}^{L(k)})}$.

5) Calculating $A^{L(k+1)} = (a_{ij}^{L(k+1)}) = \frac{\omega_i^{(k)}}{\omega_j^{(k)}}\overline{\varepsilon_{ij}^{L(k)}}$

6) k=k+1，then to the step 2.

7) Output k, $A^{L(k)}$, $SI(n,m,\lambda)^{(k)}$ and $\omega^{(k)}$.

There already has been convergence proof about compatibility revision[7]. The method can get reasonable $\overline{S.I.}$ through iterative, meanwhile, it also can get iteration number and deviation distance as the evaluation index of the method.

b. The general weighted length between decision j and excellent decision is $d_{jg} = \left\{\sum_{i=1}^{m}\left[w_i\left(1-r_{ij}\right)\right]^p\right\}^{\frac{1}{p}}$.

In which $w_i$ is attribute weight, $r_{ij}$ is relative membership degree, p is distance parameter. If p=1, the distance is hamming distance, p=2 is euclidean distance. We can choose different p when calculating similarity. For the same reason, The general weighted length between decision j and poor decision is $d_{jb} = \left\{\sum_{i=1}^{m}\left[w_i\left(r_{ij}-0\right)\right]^p\right\}^{\frac{1}{p}} = \left[\sum_{i=1}^{m}\left(w_i r_{ij}\right)^p\right]^{\frac{1}{p}}$.

Based on that, the similarity between existing case j and new building is $u_j = 1/(1+\left(\frac{d_{jg}}{d_{jb}}\right)^{\alpha})$ . If α=2, it is least square optimization criterion, when α=1, it is least one-power optimization criterion. And We can choose different α according to different requirement. In addition, similarity limit should be set when calculating. Such as if the similarity limit is 0.85, two buildings can be affirmed only when the similarity is greater than or equal to 0.85, or the two buildings are dissimilarity.

(3)The amendment and reuse for solutions. After getting the data of similar cases, policy makers should make judgments according to the law of existing information. However, due to the slight differences among cases, so the solutions of target case should be amended on them so as to coincide to the law of the goal. In addition, the model should also analyses and mines the data got from similar cases to explore the potential law.

(4) The update of cases. CBR makes use of incremental active learning mode, which gets the data and information can be stored in case base as a new case for future use after completion of the new project, and the database can also be further enriched and improved to enhance auxiliary practicality and reliability of decision.

Note that, CBR prediction model in fact is based on two assumptions: first, there are the same or similar solutions to the same or similar circumstances; second, the same or similar situation will happen again. But if the assumptions in practical applications are not met, the decision makers should adjust the prediction results based on project characteristics

## 4. Application of 3D-Webgis

Seen from Fig.2, the characteristics of 3D-WebGIS platform include:

(1) Data service. 3D-WebGIS platform uses unified GIS data file format transformed from shape file data or MIF file data, and import it into WebGIS database. It also can provide comprehensive data management for data view, import and export and configuration management.

(2) Spatial modeling. It can establish spatial metadata to describe information.

(3) Data analysis. 3D-WebGIS uses accurate data for simple and complex analysis, such as ranging, measuring frequency surface and buffer analysis, overlay analysis, data association, topology of basic data. Meanwhile it also uses A Star method to do shortest path analysis.

(4) Platform scalability. 3D-WebGIS platform uses CodeIgniter Framework to develop background database access module and function processing module. And it uses Ajax and other web technology to develop ground application processing module.

(5) Platform compatibility. 3D-WebGIS is a cross-platform so that it can run on Linux, Windows and so on. Moreover, it is also compatible with Microsoft Sqlserver series, Oracle series, MySQL database and other kinds of database.

(6) Superposition of two-dimension and three-dimension. 3D-WebGIS platform uses reasonable two-dimensional and three-dimensional mapping to make two and three dimensional drawing one-to-one correspondence. Thus it can realize effective combination of two and three dimensional drawing to achieve expected drawing effect.

This paper combined 3D-WebGIS with construction risk prediction system, in order to make prediction results more intuitive and visual. And it is benefit for regional statistical analysis. Risk prediction based on 3D-WebGIS can achieve the following specific functions:

(1) It use three-dimensional graph to intuitively display distribution of various types of buildings, and comprehensively reflect the key attributes and construction information. And it also has the functions to release information for the community in a timely manner,

(2) It provides shared platform for risk management, on-line office and information inquiry. Furthermore it also can fast search and locate the existing buildings which are similar with new buildings to realize scientific management and efficient use of risk information

(3) It can provide decision support to prevent and reduce the potential risk, and collect all possible measures based on the existing cases. It also can provide a reasonable solution for the new building. Meanwhile, it sets up artificial expert database and provides authority project proposals based on the risk results by CBR.

(4) It can provide regional risk statistics and analysis of buildings and scientific basis for effective control of risks.

Figure 2. Visual effect of 3D WebGIS

## 5. Conclusion

Based on artificial intelligence, this paper emphasized on CBR technology and its key technology. Moreover, this paper improved the methods of attribute weight calculation and similarity computation when searching cases by CBR. And those methods are of some generality. There are some advantages when CBR introduced into construction risk prediction as following:

(1) It is based on analogical reasoning and of interpretability strong;

(2) Experience of completed new project can be added to the case base to continuously enrich experienced resources. So that it can realize dynamic active learning mode.

(3) It is more reliable to use experience in similar projects, because much serious or potential risks can be discovered by computer.

On the other hand, the introduction of 3D-WebGIS can provide new technology for construction project management. It also can provide a useful attempt for intuitive visualization and convenient online office.

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