Civil engineering quality monitor framework based on information theory

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Abstract. Many researches emphasized the importance of quality control in manufacturing engineering. But there are little researches in the civil engineering field. This paper pointed out that it is possible to apply process control method in construction quality monitoring based on information theory. It is possible to build a supervision model to restrain the opportunism of agents .This paper shed light on the possible application framework of process quality control in civil engineering.

Introduction

Many researches emphasized the importance of quality control in construction engineering. Parra el at. [1] emphasized the importance of process monitor in software quality control. They pointed out that erroneous requirements, if not detected early, may cause many serious problems, such as substantial additional costs, failure to meet the expected objectives and delays in delivery dates. Chen el at. [2] built an enterprise quality management system based on process oriented method. They have accomplished an automated model to manage the workflows and resources.

There has been a wide application of computer aid process quality monitoring. Wang el at. [3] built an assembly quality control threshold optimization based on BP neural network and the results showed that the assembly precision, stability and efficiency are improved. Akande el at. [4] introduced a process quality control method for selectively laser sintering polyamide powders. But there are rarely an application of process control in civil engineering. This paper tries to discuss on the possible application framework.

The necessity of process and information to monitor

At present, the monitor problems of this domain mainly adopt monitor mechanism based on contracts. However, the monitor theory based on contracts usually ignores the process. Based on rational man supposition, such monitor theory generally constructs theoretical optimal contracts by constructing optimizing models. Its' performance in practice is often the contracts frameworks between bailors and deputies; or some frameworks involving third-party, such as frameworks based on insurance contracts. But such monitor theories have obvious shortages. Vulgarly speaking, opportunistic behaviors are the deputies' self-benefit behaviors making use of the "opportunities" due to information asymmetry, and these "opportunities" can't be supposed and predicted exactly by contracts because these coming from process.

Thus it can be seen that we have to research the process if we want to make accurate control of projects construction process. Especially for construction projects construction in possible complex environments, we must make full consideration of the process complexity. In allusion to all factors in projects construction process , we need establish matching theory models. And on the base of models with sufficient fineness, matching monitor implement technical proposals can be made. For more complex construction engineering, usually it requires more accuracy monitor to engineering construction objectives which requires not only constructing monitor methods in theory, but also establishing technical implement frameworks aiming at construction project construction objectives.

Quality monitor framework based on process-information theory

In the 1940s, it made great progress in communication domain due to the A Mathematical Theory of Communication published by the American engineer and mathematician Shannon. In the paper, it says that the basic problem of communication is recovering information at one point accurately or approximately chosen in another point. The basic communication problems include point-to-point communication, multipoint-to-multipoint communication, past-to-future communication (storage problem), etc . General communication system model is as shown in Fig. 1.

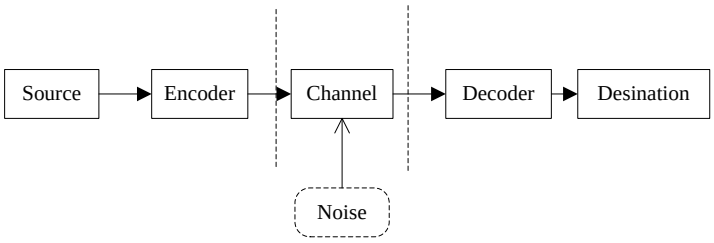

Fig.1 General communication system model

Though traditional basic communication system focuses mainly on the efficiency problems of information delivery in grammatical level, it provides thinking for monitor theory in this paper. Though information asymmetry is the source of monitor problem talked in this paper, and it can be seen as deputies' initiative concealment or forgery to some key pragmatic information. Therefore, one main reason of this problem coming into being is that pragmatic information which has main effect on eliminating information asymmetry isn't gathered, delivered and explained to relevant superintendents in an effective and accurate way. To solve this problem, enterprises should establish a mechanism which can gather, deliver even explain main objective information in process accurately. Besides, this mechanism should meet the requirement of monitor costs.

According to information theory, in the process of information delivery, the confirmation from grammar information to pragmatic information has certain theoretical basis. The definition of information entropy is on the basis of probability theory and random process. Take the example of discrete random variable, the entropy of one discrete random variable X is defined as it's information mean value, normally noted as H(X).

$$H(X) = -\sum_{x} p(x)\log p(x) \tag{1}$$

When inferring with maximum entropy theory, two factors information source type and constraint type need be ensured firstly. Take the example of discrete information source, set one discrete information source entropy:

$$H = -\sum_{i=1}^{n} p_i \log p_i \tag{2}$$

Set it's constraint:

$$\begin{cases} \sum_{i=1}^{n} p_i = 1 \\ \sum_{i=1}^{n} p_i g_r(x_i) = a_r, (r = 1, 2, ...m) \end{cases} \tag{3}$$

First constraint shows the normalization constraint of probability. In second constraint, $g_r(x_i)$ is a known function and a_r is a known constant. m is the amount of constraint conditions.

According to discrete maximum entropy distribution theorem, probability distribution meeting the conditions above can be expressed as:

$$p_i = Z^{-1}\exp[-\sum_{r=1}^{m}\lambda_r g_r(x_i)], (i = 1, 2, ...n) \tag{4}$$

Thereinto,

$$Z = \sum_{i=1}^{n} \exp[-\sum_{r=1}^{m} \lambda_r g_r(x_i)] \tag{5}$$

maximum entropy is:

$$H_{\max} = \ln Z + \sum_{r=1}^{m} \lambda_r a_r \tag{6}$$

There into,

$$a_r = Z^{-1} \sum_{i=1}^{n} g_r(x_i) \prod_{k=1}^{m} a_k^{g_k(x_i)}, (r = 1, 2, ..., m) \tag{7}$$

$$a_r = \exp(-\lambda_r) \tag{8}$$

During the time of monitoring engineering construction objectives, if information source is added to deputies' some behavior, the information p_i from this could reflect it's some behavior distribution. If information is delivered accurately by some technological method, the superintendents can get the information. It comes up with a problem that how to avoid concealing information source and blocking signals' delivery from deputies. If we have matching observing methods with different engineering construction objectives and figure out certain $g_r(x_i)$, we can infer pragmatic information of agent's actual behavior. Schematic diagram is shown as Fig.2.

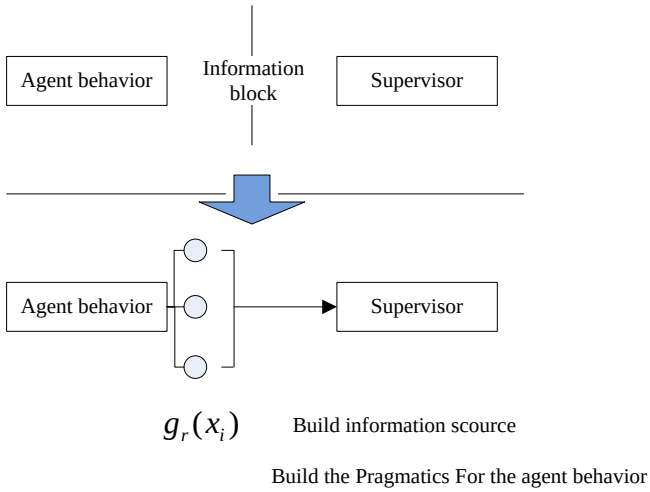

Fig.2 the map of supervision principle

But it need point out that the distribution of real behavior is complex because pragmatic information is complex in monitoring which involving complex social knowledge reference. For example, for environmental objective, if it's observed that soil piles and clitter aren't transferred or covered in engineering, we can be sure that the default probability of the environmental objective is 100%. It's complex, however, to infer the default behavioral nature in overall process hereby. Therefore the analytic solution of pragmatics default information isn't stated. The idea of realizing monitor theory in this article is that how to provide information gathering and reduce the work of information entropy technically.

Seen from the three levels of information, grammar information, semantic information and pragmatics, a monitor framework is built in which information source is built in agency by agreement, transferred to signals effectively and transmitted to superintendent on basis of cost. The framework can even transfer grammar and semantic information to pragmatic information, eliminating deputies' concealment pragmatic information to some extent. So, it can realize impairing and controlling, to some extent, information asymmetry which is the

basic factor of studying problems. The framework is shown as Fig.3. It will be stated that in this monitor framework, monitor game equilibrium could be changed in the following chapter.

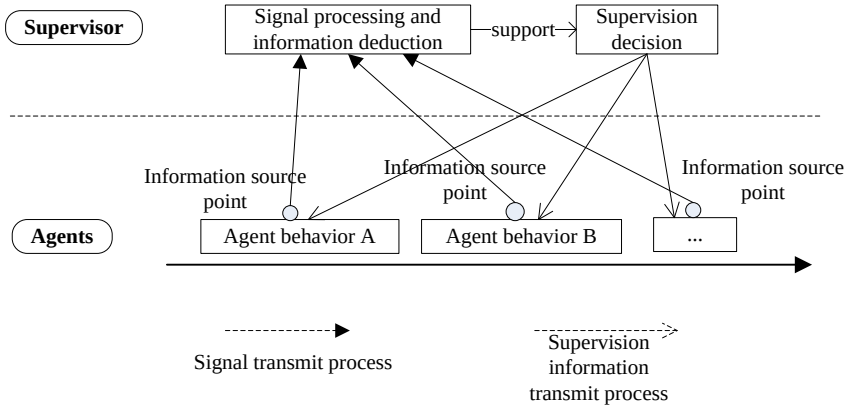

Fig.3 the framework of the supervision method

Conclusion

In the article, it points out the necessity and feasibility of construction project construction monitor and monitor framework which can impair agent information asymmetry on basis of information theory. Three factors are vital to monitor framework which are information source choice, pragmatic information analysis and relevant cost.

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