VISUALIZATION OF CONSTRUCTION PROGRESS MONITORING

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ABSTRACT

This paper proposes several visualization techniques for progress monitoring. When there is a discrepancy between as-planned and as-built progress, the decision making process seeks to offset the discrepancy. However, current mediums used in the decision making process, such as documents, graphs, charts, and still photos, may not facilitate understanding the situation clearly and quickly. In particular, considering the fact that the parties involved in this decision making process do not often have much knowledge of complex construction situations, there is a need for the tool that makes them understand clearly and quickly without developing expert knowledge. For that purpose, visualization, particularly based on the user's capacity and need, is proposed, which aims to help the involved parties' understanding of the situation and in turn, facilitate the decision making process. To that end, the potential application of metaphor, augmented reality, and color and color gradients to progress monitoring is discussed in this paper.

KEY WORDS

Progress Monitoring, Visualization

INTRODUCTION

Construction can be defined as process-based work that is performed at unfixed locations by a temporary alliance among multiple organizations [Slaughter, 1998]. These features, along with the fact that construction is carried out in open environment, make it difficult to maintain the expected progress during actual execution (e.g., frequent errors and changes). Corresponding results are schedule and cost overruns, which are prevalent in the construction industry.

One approach to this situation is to develop an effective progress monitoring process (in this paper, monitoring includes data processing before control). By capturing the discrepancy between the planned and the actual progress promptly, appropriate control actions can be made in a timely manner and thus, the discrepancy can be minimized. In this sense, the means of representing this discrepancy is one of the keys to support the decision making process for control actions. Furthermore, this decision making process often involves the parties such as the owner and the end user, who may not have much knowledge of construction situations. Thus, it may take a considerable time before the problem is

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understood in the decision making process. One study reports that 90% of the time in construction meetings devoted to describing the problem, explaining the rationale of decisions, and evaluating goals to be sure requirements are being met. Only 10% of time is spent on the real decision-making such as the discussion about what-if scenarios [ENR, 2005]. One of the major reasons for this is the limitation of mediums that represent this discrepancy. For example, text information (e.g., description of inspection results), graphs or charts (e.g., progress S curve), and still photos are typically used to monitor results in the construction industry. However, these may not be sufficient to intuitively show any discrepancy. The fact that it is difficult to understand the situation clearly and quickly with the current formats is particularly troubling, considering the need for frequent remote and quick decisions in construction. As such, the effective representation of progress discrepancy is needed to save time spent on time-consuming preparations for the actual discussion in the meeting.

As an effort to address this issue, the visualization of construction progress is explored through this research. Visualization has been reported as an effective monitoring process [Kamat and Martinez, 2003] and currently, considerable research is ongoing. In this paper, diverse visualization techniques are discussed to intuitively identify the discrepancy between as-planned and as-built data. Particularly, the main focus of this paper is visualization based on the user's capacity and need. As discussed earlier, certain construction information such as complex schedule networking may not be helpful to the involved parties who don't a have sufficient knowledge base. Thus, when visualization takes into account the user's capacity and need, the benefit of visualization can be maximized. Keeping this in mind, the paper explores diverse visualization techniques and discusses their application to progress monitoring.

METAPHOR

In some cases, excessively detailed visualization may not be necessary. For example, when high level management personnel are interested in the progress of a project, their main concern would be projects' general performance as measured by schedule and cost. In this case, metaphor can be used to represent the status of schedule and cost of the projects [Song et al., 2005]. Suppose the chief manager in the Department of Transportation (DOT) is taking care of a bridge project. The schedule and cost performance of a bridge can be represented by a visual motion metaphor in a small window in a computer screen: weather represents schedule and earthquake represents cost. As seen in Figure 1, if it rains, there is schedule overrun. In particular, how hard it is raining represents the severity of schedule overrun. Additionally, if the bridge is shaking due to an earthquake there is cost overrun. Of course, the degree of shaking represents its severity. Thus, in Figure 1 A denotes the situation where schedule is overrun while cost is not. Both rain and earthquake come from common perceptions in construction: they are bad for construction. In addition, the SPI (Schedule Performance Index) and CPI (Cost Performance Index) in Earned Value Analysis are displayed for further detail. Given this generally information, the chief manager can take consequent actions accordingly (e.g., getting detailed information and calling for the meeting). Thus, metaphor can be used in many situations where information in detail is not necessary.

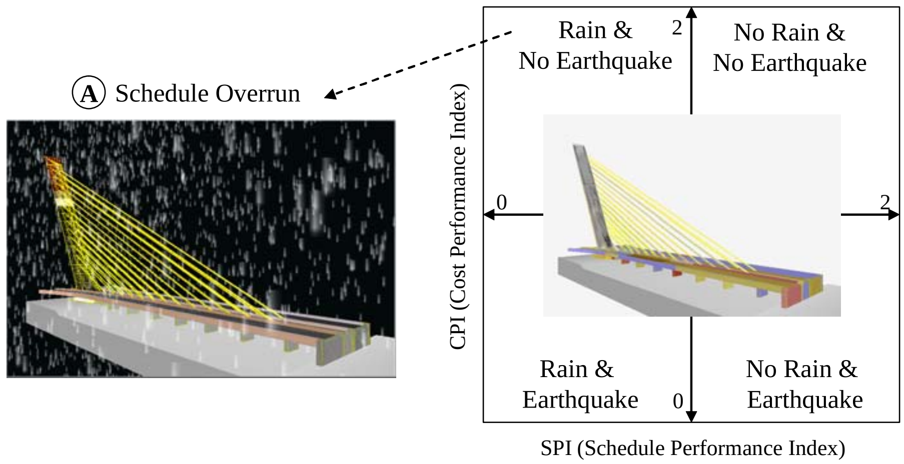

Figure 1. Visual Motion Metaphor [extended from Song et al., 2005]

AUGMENTED REALITY

Another way of representing construction progress is the use of Augmented Reality (AR). AR means putting virtual objects into real immersive environments. Applications of the blend of a virtual and a real environment are the recent focus of attention in construction. For example, Kamat and El-Tawill (2005) proposed rapid post-disaster evaluation of building damage using AR. Wang and Dunston (2005) used mixed reality for the purpose of on-the-job and off-site training programs and facilitating the collaboration process for design and construction. However, applications of mixed reality (or augmented reality) to the progress monitoring have not yet been addressed.

In progress monitoring, an as-planned image, obtained from a 3D model, is superimposed on the as-built image, obtained from the construction site. For example, Figure 2 illustrates the planned 3D model of the building superimposed on the real construction image as of today. Given the superimposition of the images, work completed and work remaining can clearly be visualized. Thus, superimposing the images provides a clear comparison between what was intended (i.e., as-planned) and the current state (i.e., as-built). In addition, the use of real images enables the representation of the temporary structure at the site so it can be useful to understand the current situation better, which is also highlighted in Figure 4.

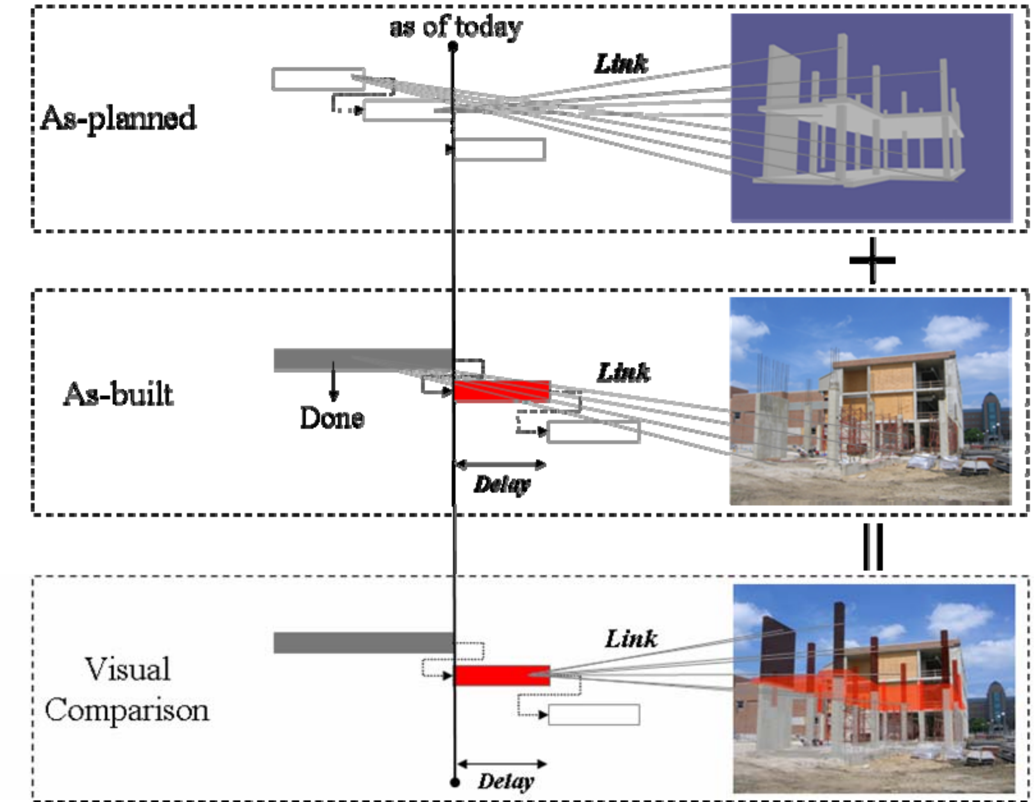

Figure 2. Augmented Reality-based Progress Monitoring

This AR image can also be linked to the schedule so that deviation in schedule can be quantified. For example, Figure 2 further illustrates that the second floor and columns that are supposed to already be installed, are the second activity in the network. Thus, we can easily quantify the deviation and in turn, trigger other information related to this activity (e.g., resource and budget information). Figure 3 illustrates a visualized report of progress monitoring. In particular, different colors are used to represent behind and ahead of schedule. For example, in Figure 3 green means ahead of schedule, and red means behind schedule. Ultimately, these benefits from AR-based progress monitoring can facilitate the coordination process by reducing the time to inform the participants as to what the situation is though they don't have much knowledge on construction systems.

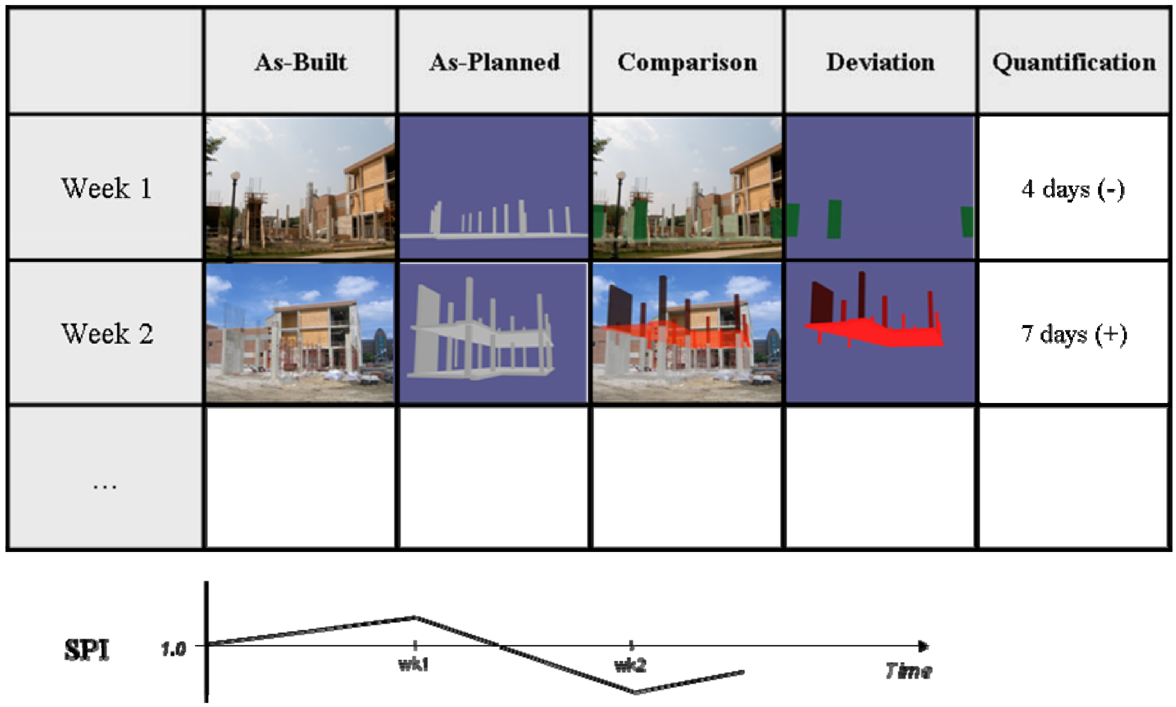

Figure 3. Visualized Progress Monitoring History

On the other hand, as-built data obtained from the laser scanner can be used for this AR-based progress monitoring. In this case, more accurate comparison and quantification will be possible because the laser scanned image can be converted into am accurate 3D as-built model.

COLOR AND COLOR GRADIENT

Another visualization technique is the use of color and color gradients. Color has been widely used for visualization of construction information [Songer and Hays, 2003; Song et al., 2005]. In progress monitoring, color can be combined with the previous AR imaging to represent diverse information in a single image. Different from the use of color in the previous section, color can be used for work packages while gradients represent work sequences in each work package. In Figure 4, two work packages are exemplified: one is the work package for the second floor in the office entrance denoted as A (red) and the other is for the second floor in the main building denoted as B (yellow). In addition, each work package's work sequence is represented by a color gradient. For example, as the gradient grows darker, there are more preceding activities. By differentiating work packages and their sequences by color and gradient, a single image can be rich in information. Along with intuitive progress comparison by AR, color and gradients tell us that how activities are associated with the comparison between as-planned and as-built data. Thus, color and gradients can give rich information which helps quickly understand the current situation and decide what to do if there is a need to reduce the gap between as-planned and as-built.

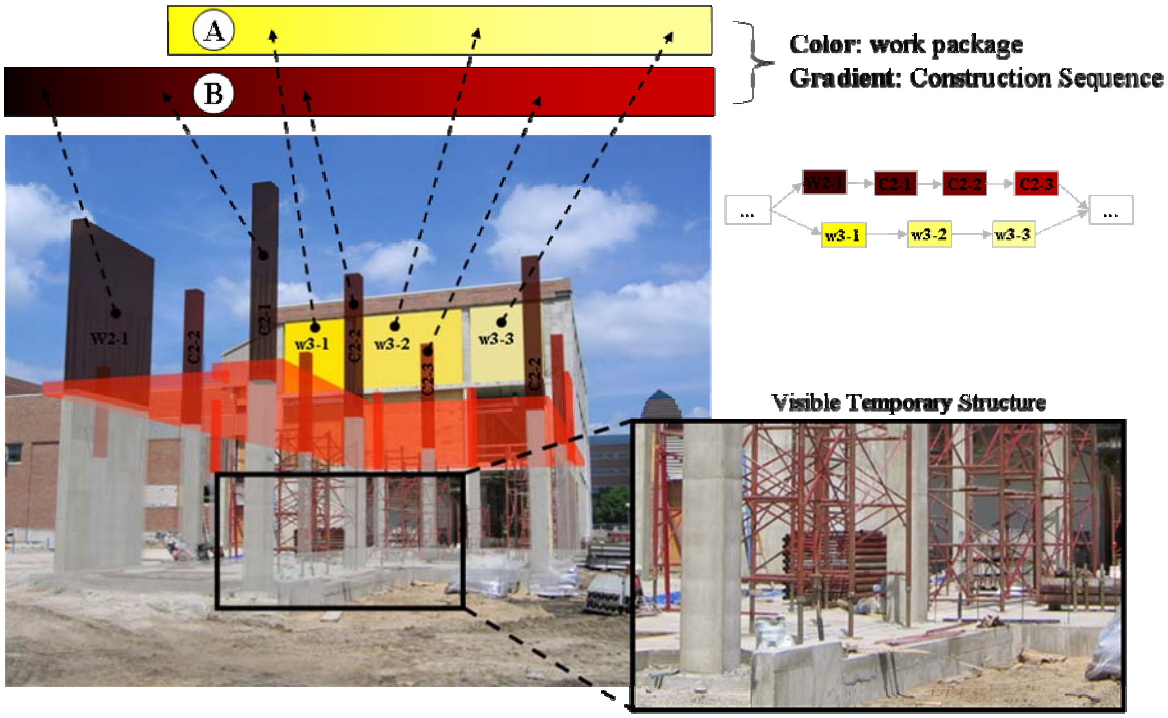

Figure 4. Use of Color and Color Gradient

CONCLUSION

This paper discussed several visualization techniques for progress monitoring, particularly for helping people who do not have much knowledge on construction situations. As a starting point, several visualization ideas and possible applications to progress monitoring were discussed. For validating these ideas, actual implementation and usability tests are needed. The authors will report such results in the near future.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contribution to this paper by Dr. Kyuman Song. We also would like to thank Do-Hyoung Kim, Graduate Student at the University of Illinois at Urbana-Champaign and Joon-Oh Seo, Graduate Student at Seoul National University.

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