REAL TIME INTERACTION AND HANDLING TOOL OF HISTORICAL DATA ON TIME-LAPSE RECORD FOR CONSTRUCTION MANAGEMENT

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ABSTRACT
This paper introduces a novel tool for interaction and visualization of real-time time-lapse videos, which can be applied to small, medium, and large-sized civil construction projects. The tool called Timelapse Player Bidimensional enables the user to visualize and analyze high-resolution photographs from a large remote database catalogued chronologically using the Quadtree technique. The usage of the Timelapse Player Bidimensional supports the user with a detailed temporal analysis in many aspects, such as process identification, productivity, delivery of material, accident investigation, disputes, delays, and monitoring the progress of construction sites.

Keywords: Photographic Recording, Time-Lapse, Collaborative Decision Making, and Tangible Interface

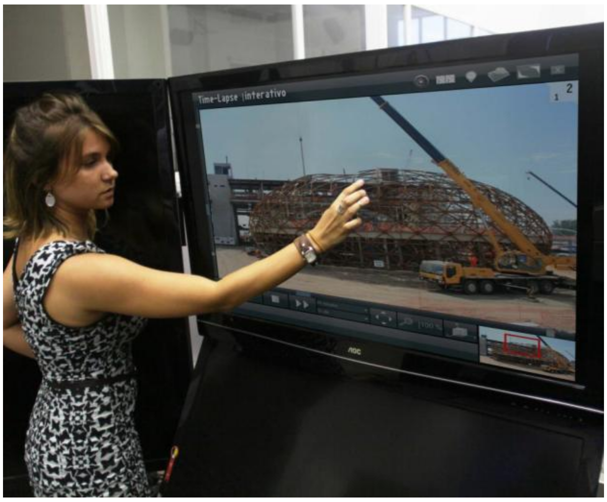


Figure 1: Visualization tool being used with a touch table device.

1. INTRODUCTION

New methods for managing projects through visualization technologies are becoming a standard, especially in outdoor scenarios and in large enterprises (Portalés et al., 2010). Photographic images are being used to monitor and assess construction operations for managerial issues. Companies are using pictures that gather information on activities related to the construction site. These records can be of great value for the identification and solution of management problems in constructions, as shown in Abudayyeh (1997).

With the advancement of technology and high performance computing, it is possible to use photographic records databases for tool condition monitoring (Dutta et al, 2013) and as parts of tools for decision-making. Image processing techniques are being applied to interpret and analyze captured data using an approach that can be manual or automated.

Time-Lapse is a technique that first captures a sequence of images at lower frequency, then the events it's registering, and afterwards reproduces the content faster than the original event. It is also important to consider the artistic relevance of photographic recording in time-lapse production and how it alters the perception of project development, by allowing decision makers to view weeks, months, or years of work in a compact time frame.

This paper presents an engineering project analysis system based on photographic event recording.

We provide a way of interacting with these records through an interactive media player capable of navigating through the results using a two-dimensional timeline controlled by the user in real time.

The system can be treated as a visualization tool (see Figure 1) and is particularly interesting for analyzing works from a remote location. Since it is an interactive and intuitive tool, it allows temporal analysis from the visualization of a selected period.

1.1. Related work

Project management through continuous photographic records to generate videos is not a system commonly employed for managing construction supervision, although the concept of using this feature as a monitoring tool is not entirely new. Few works discuss the relationship between fast image access and tangible interaction. Abed and Arditi (2002) presented such a proposal, discussing storage space issues and video production, but without considering access possibilities beyond simple video playback.

Usually this kind of image treatment and manipulation can be found in microscopic photography and satellite images; little has been discussed on this subject in the field of civil engineering. The work of Yamaoka, Doerr et al. (2011) overviews the display wall option for viewing high-resolution images.

2. OVERVIEW

The purpose of this paper is to present an approach to interactively visualize a large collection of high-resolution images in a display environment for construction managers. Timelapse Player measures and highlights critical points in the construction monitoring, identifying processes, safety, problems with suppliers, disputes and activity follow-up.

This project intends to create a series of visualization solutions capable of interacting with collected data through different physical environments. The concepts applied can be used in other tools (as shown in Figure 2).

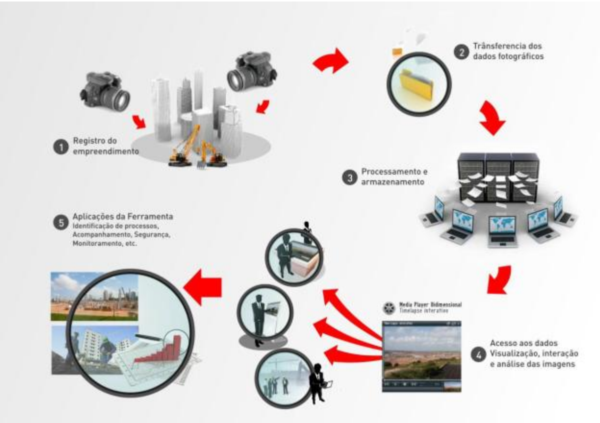


Figure 2: Scheme of the proposed system

Timelapse Player Bidimensional manipulates high-resolution digital images that, when displayed in sequence, create a movie with images from the construction site. The software runs on a remote computer, and was designed to operate with an undetermined number of cameras collecting these images through a video server located at the construction site.

The tool requires the use of several components, including a computer, at least one high-resolution camera to take pictures, and a video camera for real-time visualization (live view), a video server, internet connection, coaxial cables, and accessories.

The tool is a solution comprising five steps:

1. Data collection;

2. Data transfer;

3. Cataloging, storage and processing;

4. Description of images composition;

5. Data visualization, interaction and image analysis.

2.1. Data capture

Step 1 (Figure 2) represents an external environment of construction in which the solution for tool operation must be installed. At this stage, it is important to choose the installation judiciously so that the quality of photographic records is not compromised. It is essential to perform a study of the construction site to evaluate if a structure could grow in front of the capture point. Climate conditions, sunrise and sunset hours should also be taken into consideration. The development of this project was based on construction, however, the tool can be used in other fields, including indoor environments.

The image capturing system defines the quality and frequency of the images to be analyzed. As the main interest in this case is the analysis of remote construction sites, a device capable of capturing high definition images was chosen, allowing a better perception of the details of the events.

It was necessary to create a physical metal structure to fix the devices and protect them against weather events, since the capture system is fixed mostly in outdoor locations (see Figure 3).

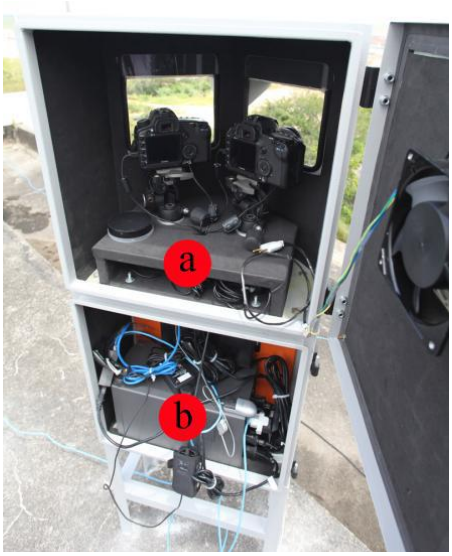


Figure 3: Example of the capture system. a) Cameras; b) Local machine for storing data.

The idea is to fixate the capture point and interact with the system remotely. Thus, it is necessary to create a tool that allows the manipulation of cameras and automatically stores captured images into a disk. This tool must have versions for client and server, and a local network must be created for the communication between them.

The server version should support the handling of files obtained by the camera, making local copies and sending them through the network. The client version must support the control of camera properties (such as aperture, focus, zoom, etc.) and also be able to remotely capture images and change the frequency of recordings.

The periodicity of the image capture is critical for the alternation of results. It will determine not only the amount of data to be stored, but also control the effect of continuity in time/space in a sequential viewing of the images. For this project, we used a capture interval of five minutes, but this interval may change depending on the speed in which the events take place in the project to be analyzed.

2.2. Data Transfer

Step 2 (Figure 2) is responsible for transferring data collected at the construction site to a local HD. Then, it will be transferred to a remote database. The transmission of the material can be made by wireless or cable internet. It is important to note that the internet connection should have a good throughput to avoid data loss or delay in the process.

2.3. Cataloging and data processing

In step 3 (Figure 2), the images are received from the construction site, indexed and catalogued according to the order of creation of the files. The time when the image was taken is used to create its identifier according to the format:

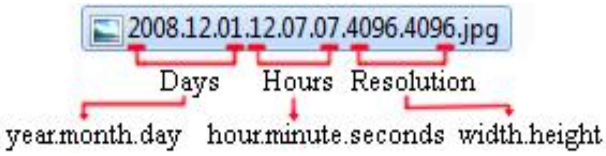


Figure 4: Identifier format.

The transferred photographic material is on a hard drive with online access for an eventual research. The photo storage location must be decided by the project manager. Data replication from the remote area to the storage station must be constantly supervised to prevent data loss. The backup physical area must be safe and in stable conditions for preserving the material, specifications such as HD type and storage space may vary according to the necessity of the project.

2.4. Description of image composition

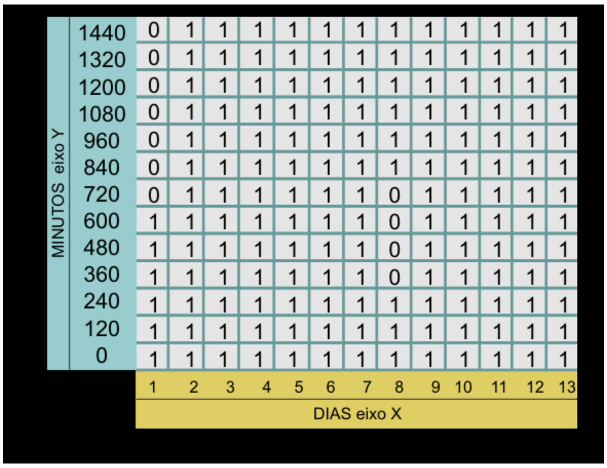
To support the process of cataloging, an array of registers is created containing all existing intervals during the time of capture. The size of the array is determined as follows:

- no. of columns = number of days;
- no. of rows = $\frac{1440 \text{ (no. of minutes in the day)}}{\text{time interval (in minutes)}}$

Thus, each array element is a binary number (see Figure 5), which indicates whether or not there is a photographic recording relative to the pair (minute/day) in time. Considering an element *i* of the array, the moment in time can be calculated as follows:

- minute = time interval * L*i*;
- day = C*i*,

where L*i* is the line of element *i*, and C*i* is the column.



MINUTOS eixo Y													
1440	0	1	1	1	1	1	1	1	1	1	1	1	1
1320	0	1	1	1	1	1	1	1	1	1	1	1	1
1200	0	1	1	1	1	1	1	1	1	1	1	1	1
1080	0	1	1	1	1	1	1	1	1	1	1	1	1
960	0	1	1	1	1	1	1	1	1	1	1	1	1
840	0	1	1	1	1	1	1	1	1	1	1	1	1
720	0	1	1	1	1	1	1	0	1	1	1	1	1
600	1	1	1	1	1	1	1	0	1	1	1	1	1
480	1	1	1	1	1	1	1	0	1	1	1	1	1
360	1	1	1	1	1	1	1	0	1	1	1	1	1
240	1	1	1	1	1	1	1	1	1	1	1	1	1
120	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	1	1	1	1	1	1
DIAS eixo X	1	2	3	4	5	6	7	8	9	10	11	12	13

Figure 5: Example of an array of record with 13 days and predefined interval between captures.

The image processing of this project refers to necessary adjustments to align the images to data segmentation operations. In these operations, pyramid-based methods are applied to all images in order to generate representations of intermediate images, depending on the desired level of approximation (for expansion). This process aims to resize the image and recursively divide it to form a pyramid of images with different resolutions and number of partitions at each level. This process takes place until the latter reaches a certain level of resolution and a linear interpolation chain is created.

The tilling process allows quick access to section images without the need to open each high-resolution image in every manipulation. This allows the image shown (by zoom and pan) to be seamingless manipulated in real time, in a very efficient manner.

2.5. Data visualization, interaction, and image analysis

Stage 4 (Figure 2) is the manager manipulation using material collected by the visualization tool (Timelapse Player Bidimensional), which promotes temporal visualization of the time-lapse selected by the user. The manager, while using Timelapse Player (Figure 6), can choose the day, month, and hour of a specific past event or from current images. After choosing, it is possible to analyze the image sequence using any frame per second rate preferred. And, finally, the enterprise manager can analyze diverse situations that could compromise the continuity of the work.

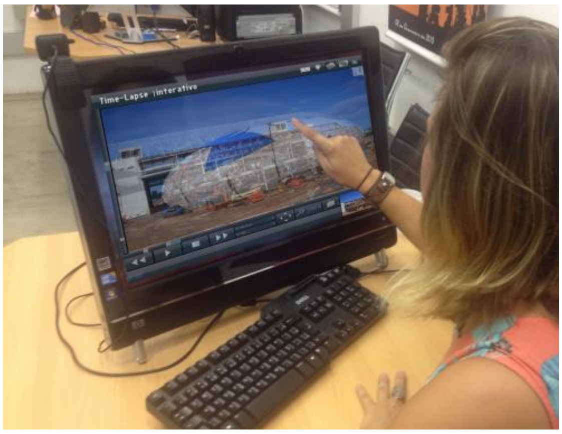


Figure 6: Visualization tool in use.

Recorded images are associated with a position in the Euclidean space, and their manipulation will be possible by switching coordinates in this space. The x-axis will be responsible for the alternation of day, the y-axis by the alternation of minutes during the day, and the z-axis remains fixed.

This step uses the array of the registers generated in the previous step to see if a registry has an associated image. In other words, the array shows the periodic intervals in which the captures were made.

At this moment, it is possible to create a playlist (containing system coordinates) to generate real-time video from captured data. The images associated with the coordinates from this list are displayed sequentially, creating a video that shows project changes during the time interval defined by the list in real-time.

The user can also interact with images trough panning and zooming operations. To do this, the pyramid-based method is critical.

As the captured images are often of high resolution, the process of loading, viewing, and switching between them would become too expensive and time consuming, making it a nonviable approach for generating an interactive video.

To solve this limitation, the display system allows the use of zooming and panning through the location of the segmented images, and the display of the visible portion of the image in the display window.

3. INTERACTION

System interaction is performed through an intuitive interface that suggests system use as a media reader, having two dimensions. Such dimensions can be represented by displacement bars in the interface, simulating a coordinate system with two axis. The manner of interaction and system features can be explained by the interface, pictured in Figure 7.

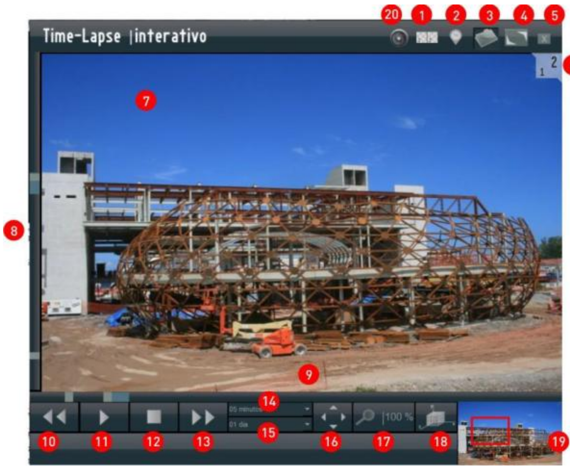


Figure 7: Timelapse Player Bidimensional Interface

3.1. Data Loading

As numbered in Figure 7, functions are divided as follows:

- Item 3 of Figure 7, registration matrix reading and storage location;
- Item 8 and 9 of Figure 7, Image visualization: Choice of coordinates (minutes, days) to identify the images that will be displayed.
- Item 17 and 19 of Figure 7, Zoom and panoramic vision: Give a more detailed analysis of happenings;
- Creation of video flows: Defines the sequence of images that should be shown;
  - Vertical: Time changes and days are fixed (item 14 and 18 of Figure 7);
  - Horizontal: Time is fixed and days change (item 15 and 18 of Figure 7);
  - Mixed: Time and days alternate, creating a time line (item 7 of Figure 7).
  - Standard player control that can be seen on items 10, 11, 12, 13 of Figure 7;
- Item 3 of Figure 7, Save video button for future evaluation and follow-up;
- Item 2 of Figure 7, Notes can be made on the video and compared to follow-up reports;
- Item 1 and 6 of Figure 7, overlapping of layers for comparison between electronic plans/models and the work evolution;
- Item 20 of Figure 7, LiveView real-time follow-up using an auxiliary security camera. Item 4 is the maximize and minimize screen. Item 16 is movement (from left, right, up or down). Item 5 is the close button.

Timelapse Player Bidimensional was a tool based on studies on civil construction to help managers in their decision-making process, in addition to optimizing activities that require documentation from past events, since quick image location can be easily performed. The user can get the material for analysis with month, date, and time precision. Such interaction is possible to the catalogue system and tool search.

4. APPLICATION

This paper shows an analysis of the use of the tool being discussed, and how it can help civil engineering in small, medium, and large ventures, helping organizational management and activity control for making decisions.

4.1 Flaw identification and assemblage and activity delays

The moving point, called NVC-Móvel, was installed with the purpose of following-up the assemblage of the Núcleo de Vizualização Colaborativa – NVC structure (Figure 8).

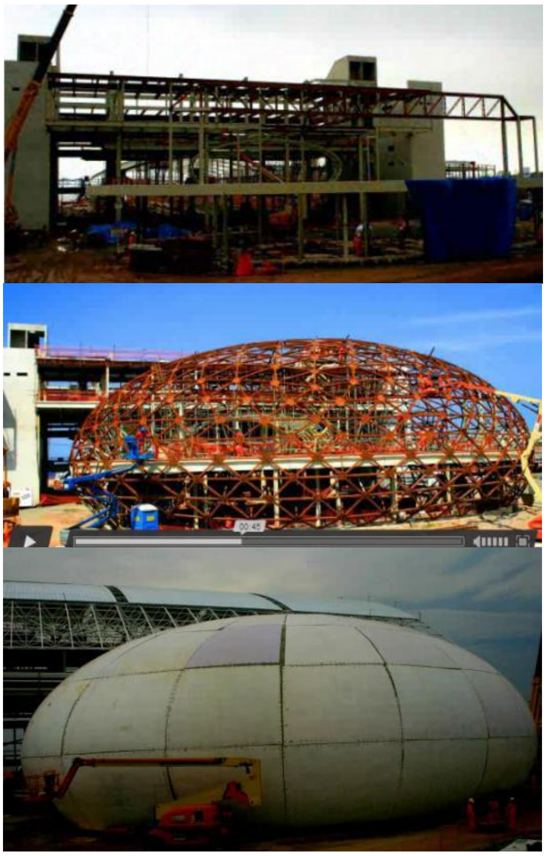


Figure 8: Image sequence from the Núcleo de Visualização Colaborativa (NVC)

Flaws and pathologies in metal structures were identified in records from almost 1 year. The NVC-Móvel camera was placed for a certain amount of time in a specific location, decided by the construction manager.

During the assemblage, it was observed that the metal structure moved and was excessively deformed in 2 different points. The Timelapse Player screen pictured in Figure 9 shows the metal structure falling. In order to avoid the structure was put at risk, a crane was rented to sustain it until the problem was solved.

Figure 9: Timelapse Player screen showing the NVC metal structure.

During the NVC construction video, it is possible to see the image sequence that shows the structure slowly falling over the course of several days. A detailed analysis can be done using the tool, as pictured in Figure 10. The zoomed image shows structure flaws in detail.

Figure 10: Close image of the NVC metal structure falling.

Another discovery took place during the observation of the installation of the pre-made plates, which were delivered having deformities, creating problems during the assemblage. The plates were irregular, which made it difficult for them to fit in the structured and compromised the finishing process. The deformity of the plates (Figure 11) added extra costs to the venture’s budget, in addition to compromising the delivery date.

From the images collected by the NVC-Móvel point, it was possible to observe, with help from the tool, the flaws in the material delivered for covering and finishing the NVC. The zoom performed by the tool (Figure 12) proves the lack of quality for assembling the project.

Figure 11: Timelapse Player screen showing the defective plates during the NVC assemblage.

Figure 12: Close image of NVC's plates.

The analysis also identified the downtime of equipment and human resources in the construction site. Some of the problems during the NVC assemblage forced equipment and personnel to be moved, making a negative contribution for the delay of the task sequence in the construction site.

During the image capture process in both points, Torre-Pan and NVC-Móvel, some unexpected events took place, caused by server failure, Internet, or cameras. Analysis results were not affected by these problems, however, it should be mentioned that maintenance needs to occur frequently so that the nature of records and the loss of relevant construction information are not lost.

5. CONCLUSION AND FUTURE WORK

Photographic evidence from the venture give a variety of new manners of analysis. Photography-associated video is a great source of research that surpasses the operational environment since the strategies used can be perfected, and new manners of analysis and applications can be defined.

Typical applications include productivity analysis, accidents, investigations, litigations, delays, construction operation remote monitoring, educational videos, etc. Such applications require the capture and reproduction of the image sequence through a tool that displays the construction operation video for a detailed analysis.

Timelapse Player Bidimensional presents a completely new approach for visualizing a remote, chronologically organized, high-definition image bank. The tool exhibition system consists in the use of two techniques: tiles bounds, which are regular divisions that reduces image processing, making loading lighter, and *Quadtree*, which allowed quick access to images due to space subdivision.

Aside from digital images being a proof with legal value, they can be directly consulted when searching for process identification information and activity follow-up.

This paper can be extended to integrate a project management system such as MS Project and Primavera. They are commonly used for managing projects and allow a more detailed control of events, creating spreadsheets and diagrams showing the progress of activities.

ACKNOWLEDGMENTS

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REFERENCES

Abed, J. and D. Arditi (2002). "Time-lapse digital photography applied to project management." Journal of Construction Engineering and Management-Asce **128**(6): 530-535.

Abudayyeh, O. (1997). "A Multimedia Construction Delay Management System." Microcomputers in Civil Engineering 12: 183-192.

Portalés, C., J. L. Lerma, et al. (2010). "Augmented reality and photogrammetry: A synergy to visualize physical and virtual city environments." ISPRS Journal of Photogrammetry and Remote Sensing **65**(1): 134-142.

Yamaoka, S., K. U. Doerr, et al. (2011). "Visualization of high-resolution image collections on large tiled display walls." Future Generation Computer Systems-the International Journal of Grid Computing and Escience **27**(5): 498-505.

S. Dutta et al. (2013). "Application of digital image processing in tool condition monitoring: A review". CIRP Journal of Manufacturing Science and Technology (6):212–232.