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Augmented Reality to Access Dam Cracks Information

Fabiana Frata Furlan Peres[1], Sergio Scheer[2], Étore Funchal De Faria[3], William Antonio Da Rosa[4]
[1](*Center of Engineering and Exact Sciences, Western Paraná State University, Foz do Iguaçu, Brazil)*
[2] *(Department of Civil Construction, Federal University of Paraná, Curitiba, Paraná, Brazil)*
[3] *(Division of Civil Works, Itaipu Binational, Foz do Iguaçu, Paraná, Brazil)*

ABSTRACT
Augmented reality technology is a tool with great potential for application in several areas, including engineering. During the early phases of the enterprise life cycle, as design and construction, augmented reality has been widely used. Concrete dams, during operation and maintenance phase, require regular inspections as part of the necessary activities to keep their structural safety. Cracks are common pathology in these structures that must be detected, mapped and measured as their evolution may evidence structure compromising, need for maintenance or intervention. In this context this paper aims to present a prototype to access in situ the dam cracks information through the use of augmented reality, thus giving a contribution to the effectiveness and efficiency of inspections.
***Keywords*:** augmented reality, crack, dam, dam safety, dam inspection

I. INTRODUCTION

During the last two decades, it has been searched computing tools to support activities related to engineering in order to organize and integrate all the digital documentation regarding buildings. *Building Information Modeling* (BIM) is a technology for this proposal. It generates a digital representation of the physical and functional characteristics of any built object, producing a virtual representation of the construction along its whole life cycle [1]. This representation has been explored in field via augmented reality technology [2, 3, 4, 5, 6, 7.8].

There are many built and under construction dams worldwide. Although most of them is already in operation, they have neither been designed and nor constructed using BIM. There is a constant effort to modernize them, adopting current technologies to support activities related to itsoperation and maintenance [9, 10].

It is very important that the dams in operation are kept safe throughout their life cycle. Thus it is necessary to periodically perform dam safety activities, such as visual inspections, in order to detect early signs of pathology. Cracks are common pathologies in dams and require the monitoring of their progress over time.

In recent years, researchers have tried to innovate the way that inspections are performed. With respect to cracking, several alternative to conventional methods for detecting, mapping and measure them have been proposed [11, 12, 13, 14, 15, 16, 17]. These alternative methods generate large volumes of information. Accessing them properly in field is very important and can make the evaluation process more efficient and effective. In this context augmented reality is an advantageous technology, since it mixes real and virtual information, enabling data, images and other information generated about the cracks coexist in the real environment.

This paper presents an augmented reality prototype for in situ access to concrete dam crack information. It demonstrates the feasibility of using augmented reality technology in dams, specifically in structural safety activities, to monitor the development of cracks. It also allows the proper use of data extracted in related activities in the operation and maintenance phase.

In section 2 is defined what is augmented reality and a discussion about its use in the context of *Architecture, Engineering and Construction/Facility Management* (AEC/FM) and BIM is introduced. Afterwards, in section 3, it is discussed, in general, dam safety showing of what comprises and its importance in the context. In the section 4 it is described the conventional procedure and some proposed alternative for mapping and monitoring of the crack in concrete structures. Finally, the proposed prototype is covered in section 5 and some conclusions are presented in section 6.

II. AUGMENTED REALITY

Augmented reality can be defined as an innovative way for data visualization, images and information. This technology mixes virtual content, generated by computer, to real environment to enrich the senses, usually the sense of human vision [18].

Despite the basic technology have arisen in the 60's, only in the current decade, after the evolution of devices and frameworks for the development of augmented reality, is that its popularization has occurred.

Azuma asserted nearly two decades ago the existence of at least six potential classes of augmented reality applications, letting it be understood that others could emerge [19]. Currently its range of use is broad, it's sometimes still hampered by lack of adequate resources.

In engineering augmented reality has become a bridge between the large amount of data produced in projects at offices, by engineers and designers, and the construction site.

1.1 Augmented Reality in Engineering

The complex nature of AEC/FM and the demand for access to information increase the need to use information technology.Throughout the life cycle of buildings large volumes of complex data is produced such as design drawings, images, schedules and others. Recent research has identified many beneficial capabilities of using augmented reality in the AEC/FM for the visualization / simulation, information retrieval and interaction [20, 21]. The integration of these two technologies allows, for example, that the viewer interacts with both real and virtual objects; that it's done the monitoring of the progress of a building by comparing the as-built progress against as-planned.

A review based on articles found within well-known journals about AEC/FM until the end of the year 2012, presented by [20] on the use of augmented reality in the construction industry showed that from 2008 was intensified research in order to integrate augmented reality with AEC/FM.

From the works developed searching the integration of augmented reality in AEC/FM, Kwon et al. [6] proposed two types of system. A image-matching system to enable quality inspection without visiting the real work site and another mobile-based augmented reality defect management application which enables workers and managers to automatically detect dimension errors and omissions on the jobsite [6].

Meza et al. [7] showed the use of augmented reality on mobile devices to track the progress of construction. Considering the information contained in the 4D project, where in addition to the 3D model has the schedule of work (considered the fourth dimension), the system projects onto the real environment, the 3D model of what should be the construction in accordance with the provisions of schedule [7].

Lee and Akin [8] proposed the use of augmented reality to systems for support the inspections and maintenance that add virtual components to be repaired in existing components and allows workers to easily recognize work to be done and also the workplace [8].Faria et al. [22] and Peres et al. [23] have also applied augmented reality to access dam information due to the specific features of operation and maintenance phase.

III. DAM SAFETY

Dams have been important infrastructures for the development of society for years. It can generate many benefits; however comprises a structure usually associated with a high potential collapse risk and so it is important that safety is achieved by performing a set of technical, systemic and periodic actions. The set of actions necessary to maintain the safety of a dam is the observation and maintenance aimed at keeping the design features.

The observation of a dam is supported by visual inspections and measurements by instrumentation to obtain information about their structural health. By this way, common pathologies like dam cracks can also be detected, measured and monitored to track their progress. Cracks deserve attention, since one of the main reasons for reducing its lifetime of dams are the leakages and cracks are main causes of leakages [24].

IV. CRACKS IN STRUCTURE OF CONCRETE

Cracks may be the first signs of the existence of possible structural failure, but they are not always serious [13]. It is very important to detect, map and quantify them as their evolution. The traditional method used to characterize cracks and other alternative methods to do so are presented as follows.

4.1 Methods for Characterization of Cracks

The conventional method for characterization consists of a manual process, where the sketch of the crack is made based on visual inspection. The measurement opening is made using an instrument such as a graduated magnifying glass or rule containing standard thicknesses or caliper or other [12, 13]. Such conventional method is very expensive, time-consuming, dangerous, labor-intensive and subjective [25].In dams conventional method is even worse, as they include structures with considerable areas to inspect and, depending on their shapes, the implementation of the method is hampered by the need for specialized professionals and sometimes even scaffolding assembly.

With the development and popularization of various computational technologies, alternative to traditional methods, supported by digital image processing techniques have been proposed [11 12, 13, 14, 15, 16, 17].

CONCRACK is a proposed method that automatically detects, maps and measures cracking even allowing the monitoring of crack progress [13]. Another example is the *SurfCrete* that characterizes the cracking and evaluates other damage to concrete surfaces using multispectral analysis [15].

Adhikari et al. [17] proposed to use digital image processing techniques to obtain the concrete crack properties during inspections on bridges. Other similar works proposed are described in [11], [12] and [14]. These alternative methods are based on digital images and generate a large volume of data and information regarding the cracks.

In these studies, alternative methods were presented dealing with automation of parts or all the process making use of algorithms and procedures for digital image analysis. This represents advantages in terms of speed, efficiency, information obtained volume and even reliability, since data are processed automatically and are not subject to operator errors.

An important factor not addressed refers to how to access these data in real environment where inspections occur.

V. DAM CRACKS INFORMATION ACCESS

Computational methods more efficient and automatic for detection, mapping and measurement of cracks generate a more detailed, complete and organized documentation. However it is important to access this information at the right time - in situ - during inspections, providing an increase of reality and allowing the realization of a more effective and efficient observation. A suitable technology for this purpose is augmented reality for mobile devices. The prototype presented in this paper uses *Wikitude* to apply this technology in the context of cracks in dams.

Wikitude is *Software Development Kit* (SDK) used to created augmented reality experience [26]. Fig. 1 shows the *Wikitude SDK* architecture.

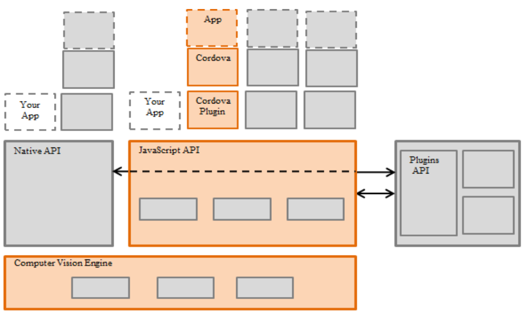

Figure 1: Wikitude SDK architecture (adapted from [26]).

Wikitude Cordova plugin was used to embed augmented reality into the *Apache Cordova* project of the prototype.

Apache Cordova is open-source mobile development *framework.* It provides *Application Protocol Interface* (API) that enable the development of applications for mobile multi-platforms using HTML5 technologies, CSS and JavaScript (Fig. 2). Its main advantage is to allow the development of applications using native resources of the platform without the need to know the specificities of native resources, which would make multi-platform development more difficult. Thus the application is coded using JavaScript, HTML5 and CSS[27].

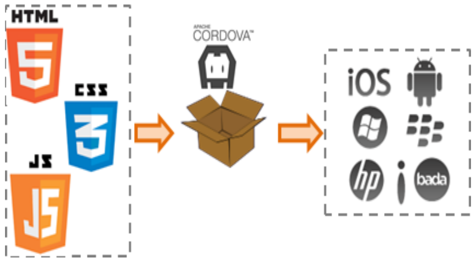

Figure 2: Cordova Applications (adapted from [27]).

The data of the cracks are persisted on the web, in a *MySql* database. The language server-side PHP was used to make the connection of the prototype with the database.For the prototype increase the reality of the cracks on the dam, it is necessary to identify the location of the real world where they are. For this, the prototype requires the geographic coordinates provided by the mobile GPS to identify the location of the viewer and the geographic coordinate of cracks stored in the database. Based on the coordinates registered the markers of the cracks are inserted in the environment, as shown in Fig. 3.

Figure 3: Dam Cracks Information Prototype screen.

The data of the cracks used in this prototype are fictitious just to perform the necessary test.Each crack stored has information about its length, direction (horizontal, vertical or diagonal) and openness. For each inspection performed there is a set of data about it persisted in the database including the date on which the inspection was carried out, the ambient temperature on the day of the inspection and crack images. The crack is classified in three classes based on its length (L) and openness (O). Table 1 shows the characteristics required in each crack class.

Table 1: Characteristics of crack classes.

Class	Characteristics
I	$\mathbf{L} \geq 6.0$ m ; $\mathbf{O} \geq 0.3$ mm
II	3.0 m $\leq \mathbf{L} < 6.0$ m ; 0.1mm $\leq \mathbf{O} < 0.3$mm; or $\mathbf{L} \geq 6.0$ m ; 0.1mm $< \mathbf{O} < 0.3$mm
III	any $\mathbf{L}$; $\mathbf{O} < 0.1$mm

Distinct colors for markers (green, yellow and red) are assigned to represent the three crack classes: Class I in red, Class II in yellow and Class III in green. Thus the class is transformed into visual, simple and easy information to be perceived by the observer. Fig. 3 also shows a screen containing markers around the cracks of different classes. A compass in the upper left corner of screen indicates cracks contained in the structures to a certain radius around the observer.

Changing the value on the shortcut 'Alcance' (Fig. 4), the maximum distance between the observer and the viewed cracks may be determined. Thus information of cracks that are far away from the observer is hidden.

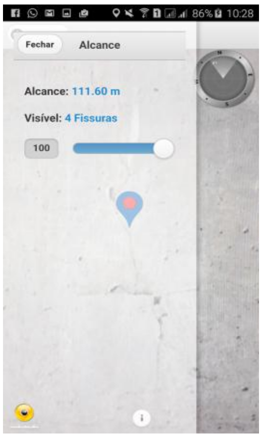

Figure 4: Screen for adjustment of "Alcance".

Mobile screen shows details of a crack selected (Fig. 5): a general description; length, opening and direction of the crack; performing dates of inspections with links to images recorded.

The features available in the prototype show that access to the volume of data collected during inspections, along the dam's life using augmented reality enriches the real environment, abstracting information and making the inspection task more precise and agile.

Figure 5: Screen showing crack details.

VI. CONCLUSIONS

The prototype presented in this paper identifies the location of the cracks in the real world and provides access to data in situ. In addition, some data are interpreted and generate simple information to be perceived by the observer, as in the case of the crack class, the prototype represented by different colors each class.

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