E-CATHEDRAL

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ABSTRACT

The E-Cathedral research program was born in the context of cultural heritage preservation. It is dedicated to the digitization of the cathedral of Amiens, in France, to get a model as complete and as precise as never been obtained. The use of this model is another important target of this multidisciplinary program merging geographical surveying, information technologies, robotics, history of art and architecture, at least.
E-Cathedral was launch at fall 2010 and this paper aims to give an overview of results obtained during its first two years of existence. Hence, digitization tools, mobile robotics and computer vision works that are used and going to be more and more used and developed in the heritage context, are presented, as well as early results on the 3D structure coloring and a first interactive and educational software.

INTRODUCTION

Cultural heritage preservation is a key challenge of humanity and is the first mission of the culture branch of Unesco[1], "to protect, safeguard and manage the tangible and intangible heritage". A way to preserve heritage buildings, in order to make them accessible to everyone, today, and in the future, is their digitization. This digitization leads to snapshots of buildings. Of course, considering huge heritage buildings, such as a Gothic Cathedral, the digitization is very challenging.
This is the context of "e-Cathedral"[2], the research program that we have launched in fall 2010, for a period of fifteen years. The aim is to completely digitize, indoor and outdoor, the Cathedral of Amiens (Fig. 1), in France, in order to obtain a 3D model of the highest fidelity, in terms of structure, color, material properties and physics. It can only be reached thanks to an exhaustive inspection of the building to achieve the finest measures.
To deal with both the structure and color digitization of the Cathedral of Amiens, we have started a joint project with the French National Institute of Geography (IGN), using laser-based scanning and photogrammetry-based[3] 3D measurements on the heritage building (Fig. 2). But due to the size and complexity of the Cathedral of Amiens, of which the volume is twice the one of the Cathedral of Paris, it is clear that robots, on the ground, on the walls and in the air, can be very useful to help the digitization and to improve and complete it. For this purpose, mobile robots of any kind should have a sure autonomy, particularly in the perception of its environment. Computer vision associated to mobile robotics has the potential to reach such an autonomy and the design and the use of non-conventional vision sensors, such as omnidirectional cameras, as well as the adapted processing of the images they acquire are revealing this potential. Indeed, using sensors presented in Figure 3, we manage to design and develop methods of various environments safe exploration by a mobile robot [1-3], self localization [4], both in the context of the ANR (French National Research Agency) funded project R-DISCOVER, and visual path following as an extension of visual servoing [5]. By embedding conventional and non-conventional cameras on a flying robot, the precision of the former and the very wide field of view of the latter are combined to accurately estimate the orientation, altitude, motion and speed of the robot [6]. The latter set of low level measures is very useful for autonomous take off and landing, which are still not solved in open conditions.
All these technique are going to be used to design robots in the goal of precise inspection and measurement of heritage buildings. The potential of mobile robots for this purpose is to reach optimal measurement positions, to ensure the best digitization in terms of fidelity and also efficiency. This is currently an important research activity in the e-Cathedral research program, led with the cooperation of the French Ministry of Research, and recent results, of 3D laser-scans coloring, dramatically improve the 3D model fidelity to the actual Cathedral [7] (see the **RESULTS** Section).
Obtaining a complete 3D model of the Cathedral of Amiens is a very challenging research issue itself but the e-Cathedral research program is even wider, tackling pertinent navigation around and inside the 3D model, historical, artistical and safety studies, as well as education. In the context of pertinent navigation, the

[1] http://www.unesco.org
[2] http://mis.u-picardie.fr/E-Cathedrale/en/
[3] http://www.micmac.ign.fr/

"ASSIDUITAS" research project, funded by the French Picardie Region, just started at fall 2012. This project merges skills in artificial vision, knowledge management and movie direction, in order to make any user having a free navigation experience, as pertinent and pleasant as looking at a heritage documentary, but with interaction, in addition.
These aspects can finally serve education, and the e-Cathedral research project aims also to design and develop, among other tools, serious For instance, in partnership with the city of Amiens tourism office, we designed and developed an educational software learning to teenagers how a portal of a Gothic Cathedral is built, using data obtained from the digitization of the Cathedral.

RESULTS

The e-Cathedral research program results are regularly updated on the official website of the program: http://mis.u-picardie.fr/E-Cathedrale/en.

The first result is the raw digitization itself. Several techniques are used but the currently most used measures are the ones from laser scanners. At falls 2010, 2011 and 2012, three digitization campaigns, 12 days each, took place to digitize, indoor and outdoor approximately a quarter of the cathedral. Billions of measures were done to obtain 3D points on the cathedral surface, every 2 mm for the most precise areas (Fig. 4).
The second presented result is about the coloring of the measured 3D structure of the cathedral of Amiens. Indeed, the most used tools to measure the geometrical structure of the cathedral are laser scanners but, even if equipped with digital cameras, the color quality is rather bad. It is so bad that, despite a very precise structure measure, the color leads to virtual images with poor details (Fig. 5). This issue, and others, can be corrected by taking high-resolution photos and by designing a precise registration method of images on the 3D structure, leading to results presented in Figure 6. This unusual registration of photometry over geometry is inspired from our previous works on 3D model based pose estimation and localization using vision [8, 9].

CONCLUSION

This paper gives an overview of the e-Cathedral research program after two years of progressively increasing works. The raw measures of digitization are themselves a result that the new recoloring approach inspired from our previous works improves and that some educational software already uses.
Other research projects in the world and in Europe were or are dedicated to measuring and rendering in 3D heritage objects and buildings. Among them, Columbia University[4] in USA was interested in the cathedral of Amiens around 2000, even if it was more about architecture. They digitized, with means of these times, some parts of the cathedral, with a rough precision. More generally speaking, the EU funded 3D COFORM[5] project between 2008 and 2012 focused the research more on objects than buildings but shares similar heritage conservation aims than ours.
Listing all projects related to heritage digitization is not the current purpose but globally, it can be pointed out that the use of robots is lacking, even if some tele-operated platforms are sometimes used in the heritage survey. Autonomous mobile and flying robots have the potential not only to ease the work of surveyors or people in charge of restorations but also to do things that were not possible before, such as reaching very high precision in measures. The e-Cathedral research program draws such as line by merging robotics, computer vision and interaction for e-Heritage.

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[4] http://www.learn.columbia.edu/Mcahweb/index-frame.html
[5] http://www.3d-coform.eu/

REFERENCES

[1] P. Merveilleux, O. Igbida-Labbani, E. Mouaddib. **Free Space Detection Using Active Vontours in Omnidirectional Images**. In *the IEEE The International Conference on Image Processing, (IEEE ICIP 2010)*, Hong Kong, Septembre 2010.

[2] P. Merveilleux, O. Labbani-Igbida, E. Mouaddib. **Real-time free space detection and navigation using omnidirectional vision and parametric and geometric active contours**. In *IEEE Int. Conf. on Robotics and Automation, ICRA'11*, Shanghai, China, Mai 2011.

[3] P. Merveilleux, O. Labbani-Igbida, E. Mouaddib. **Robust free space segmentation using active contours and monocular omnidirectional vision**. In *IEEE Int. Conf. on Image Processing, ICIP'11*, Brussels, Belgium, Septembre 2011.

[4] R. Marie, O. Labbani-Igbida, E. Mouaddib. **Invariant Signatures for Omnidirectional Visual Place Recognition and Robot Localization in Unknown Environments**. In *IEEE Int. Conf. on Pattern Recognition, ICPR'12*, Tsukuba, Japan, Novembre 2012.

[5] G. Caron, E. Marchand, E. Mouaddib. **Omnidirectional Photometric Visual Servoing**. In *IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, IROS'10*, Pages 6207-6207, Taipei, Taiwan, Octobre 2010.

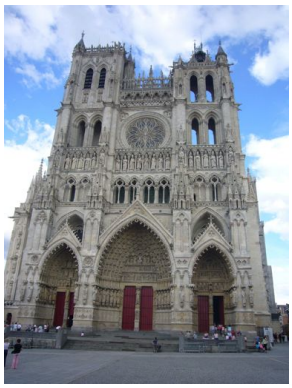
[6] D. Eynard, P. Vasseur, C. Demonceaux, V. Frémont. **Real time UAV altitude, attitude and motion estimation from hybrid stereovision**. In *Autonomous Robots*, Pages 157-172, vol. 33, n°1-2.

[7] N. Crombez, G. Caron, E. Mouaddib. **Colorisation photo-réaliste de nuages de points 3D**. In *Young researchers in computer vision congress (Congrès des jeunes chercheurs en vision par ordinateur) ORASIS'13*, Cluny, France, June 2013.

[8] G. Caron, A. Dame, E. Marchand. **L'information mutuelle pour l'estimation visuelle directe de pose**. F*rench speaking congress on Pattern Recognition and Artificial Intelligence, RFIA'12*, Lyon, France, january 2012.

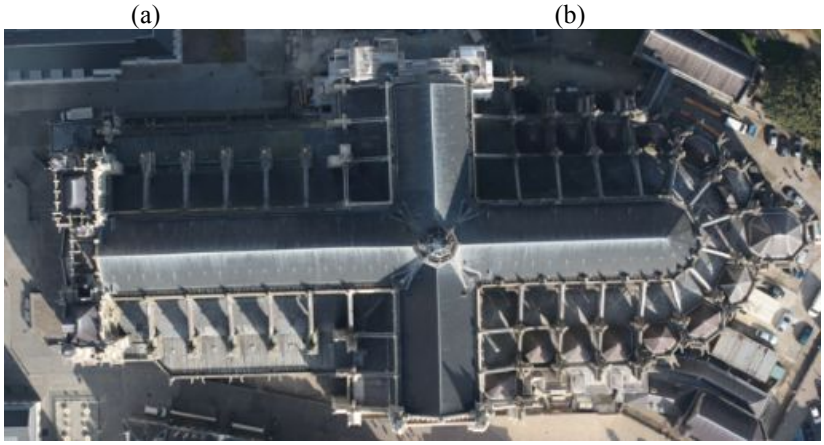
[9] G. Caron, E. Mouaddib, E. Marchand. **3D model based tracking for omnidirectional vision: a new spherical approach**. In *Robotics and Autonomous Systems*, Pages 1056-1068, vol. 60, n°8, 2012.

[10] E. Mouaddib, R. Sagawa, T. Echigo, Y. Yagi. **Stereovision with a Single Camera and Multiple Mirrors**. IEEE Int. Conf. on Robotics and Automation, ICRA'05, Pages: 800-805, Barcelona, Splain, 2005.



(a)

(b)



(c)

Figure 1: The cathedral of Amiens in France. (a) a view of its main façade. (b) inside the cathedral. (c) an orthographic aerial view of which the vertical up axis corresponds to the north: the main façade of (a) is on the west side.

(a)

(b)

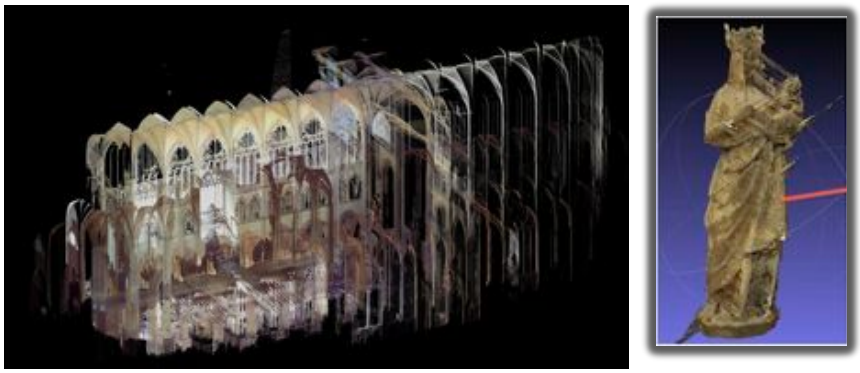
Figure 2: Tools used for the digitization of the cathedral of Amiens in France. (a) Laser scanners measure the structure with high precision. (b) Cameras acquire image that can also be used for computing structure from multiple images in addition to the color measurement.

(a)

(b)

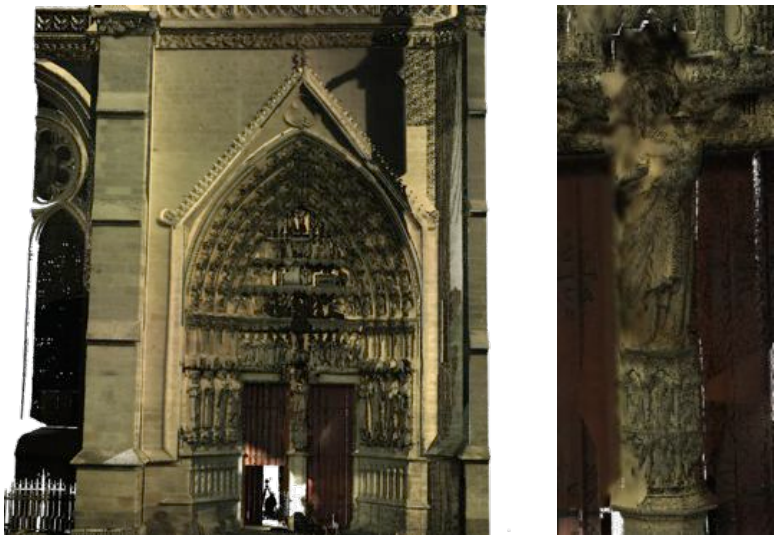
(c)

Figure 3: Some unconventional sensors with a strong potential for robotics since they capture a panoramic image at a unique time. (a) double reflection catadioptric camera. (b) fisheye camera (no mirror). (c) Four On One sensor made of one camera and four mirrors to ensure a stereo panoramic image [10].



(a) (b)

Figure 4: Early digitization results of the cathedral of Amiens. (a) point cloud resulting of the merging of several laser scanning stations. (b) point cloud resulting from photogrammetry (courtesy of ENSG/IGN).



(a) (b)

Figure 5: Raw point cloud of the south portal of the cathedral of Amiens. (a) the first 20 m of the portal from the ground. (b) zoom on the Golden Virgin statue. The low laser scanner camera quality and varying sun exposures during acquisitions lead to blurred and low dynamical virtual images despite a very precise structure.

(a) (b)

(c) (d)

Figure 6: Coloration results of the 3D point cloud from externally acquired photos. (a-b) global colorization on the south portal of the cathedral of Amiens. (c-d) focus on the Golden Virgin statue. These virtual images, which are looking as real views, have to be compared with the raw measurements presented in Figure 5.