Combining Indoor Positioning Systems (IPS) with Structure from Motion (SfM) 3D Point Clouds in Cultural Heritage

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The benefits of using Geographic Information Systems in archaeology and cultural heritage are undeniable and the use of spatial data has been crucial in shaping a wide number of research fields. Nevertheless, the transition from “Geographic Information Systems” (GIS) to “Indoor Positioning Systems” (IPS) has not been adequately studied, despite the very promising uses of IPS in cultural heritage. This paper describes research conducted at the Digital Media Lab, Technical University of Crete. The use of an IPS is being tested on a monument in Crete, Greece, in combination with a 3D Point Cloud obtained by “Structure from Motion” (SfM) Techniques. The selected monument under study is located at the seafront of the 700 years old Venetian harbor of Chania and used to be the private residence of Ambassador R. Krueger who built it on 1890. The goal is to examine whether 2D data produced by IPS can be enhanced with 3D data from SfM in order to provide an enriched experience of navigation and personalized services customized to each user’s needs. Moreover, valuable insights for improving the architectural configuration of the monument’s interior can be extracted by documenting the exact position of each user in space in real time. Software used is *Indoor Atlas* for IPS and *RealityCapture* for SfM. The study was accomplished without the use of any hardware sensors – no beacons and no Bluetooth.

Key words:
Indoor Positioning Systems (IPS), Structure from Motion (SfM), 3D Point Clouds.

CHNT Reference:
Panagiotis Parthenios et al. 2018. Combining Indoor Positioning Systems (IPS) with Structure from Motion (SfM) 3D Point Clouds in Cultural Heritage.

INTRODUCTION

Latest technology has enabled the development of spatial data advanced digital tools, thus creating an evident benefit for the urban cultural heritage sites.

> *“In the ancient nuclei of many towns, these sites are like pieces of a puzzle that has become illegible; they pose serious problems of knowledge and documentation, in addition to problems related to monitoring their state of conservation.”*
>
> [Gabellone 2009]

This paper focuses on the experimentation and future combination of two state-of-the-art technologies in the fields of spatial data acquisition and building modeling information on the same monument, the Ambassador’s Residence in Chania, Crete, which was built in 1890 as the private residence of Ambassador R. Krueger. The monument underwent major restoration in 2014 and since then functions as a boutique hotel.

In order to simultaneously conduct the two experiments, two distinct research groups were formed: the first group created a 3D Point Cloud from “Structure from Motion” (SfM), while the second group explored the potential of “Indoor Positioning System” (IPS) within the building. The first part of the paper presents the analysis, results and limitations of the SfM 3D Point Cloud process. The second part explores the IPS technology experiment within the building. The last section of the paper focuses on the potential of combining the outcome of the experiments into the

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same digital environment, aiming to produce a model that ‘can be used for the generation of a large amount of diverse information in both qualitative and quantitative formats’ [Rodriguez-Moreno et al. 2016].

STRUCTURE FROM MOTION (SFM) 3D POINT CLOUD

The initial part of the research study conducted on the monument focused on creating a 3D Point Cloud produced with SfM (Structure from Motion) Techniques. Towards this goal, the limitations, effectiveness, and software efficiency had to be investigated. The research team used the following software: *RealityCapture*[1], *Agisoft PhotoScan Professional*[2] and *Recap Photo*[3]. The 3D Point Clouds were created using a camera, a drone[4] and a video to jpeg images converter[5].

Experiment Setup Overview

Initially, building pictures were captured from different perspectives – both ground level and aerial ones – and were inserted into the selected software for further processing. The same procedure was repeated using different hardware and software for two reasons: on the one hand, different hardware was necessary to be used in order to get an accurate scanning of all the building parts. The drone was used during the scanning of the roof and upper building parts, while the cameras contributed to the scanning of the lower building parts. On the other hand, different software use served as the platform for further comparison and analysis. The various outputs were compared in terms of the process length, the process required to achieve the optimal result and the quality of the results. Supplementary pictures were taken and processed in, aiming to manage the preferred outcome.

Experiment Process

The software used processes pictures and creates the 3D model by focusing on finding common points between pictures. Hence, the photos selected for import should be as focused as possible, and have at least 30 % overlap with each other. SfM

> *“is most suited to sets of images with a high degree of overlap that capture full 3D structure of the scene viewed from a wide array of positions or as the name suggests, images derived from a moving sensor (‘motion’).”*
>
> [Hopkins Nyimbili et al. 2016]

After the selection of the images and their insertion into the software, *Agisoft PhotoScan Professional* requires the following steps for the creation of the 3D model: aligning the points of the inserted pictures, creating the 3D Point Cloud, the triangulation of the point cloud union and texture application of the 3D model (Fig. 1).

RealityCapture follows a similar process. The steps are the following: photos insertion, alignment, reconstruction (mesh creation), reconstruction result, coloring, coloring result, reconstruction region set, reconstruction region mesh creation, reconstruction region mesh result, reconstruction region coloring, reconstruction region coloring result, and finally control definition and component consolidation (Fig. 2).

Recap Photo is similar to *RealityCapture* but offers additional editing options of the model (mesh editing, etc.), and further combination with other Autodesk software (Maya, 3ds Max). Unfortunately, the educational version of the software allowed the insertion of only 100 pictures per project. The software is cloud-based in all matters that regards the creation of the model, and operates with the charge of the user with credits, depending on the number of pictures each project includes. The difference of this software compared to the other two is that the 3D model is not created on the computer, but on Autodesk’s cloud server. Once the model is created, it is available for downloading from the cloud server (Fig. 3).

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[1] Capturing Reality https://www.capturingreality.com (v.1.0.3.4658-demo version and 2-week-promo license)

[2] Agisoft https://www.agisoft.com Agisoft PhotoScan Professional 1.4.1 (30-day free Trial License)

[3] Autodesk Recap https://www.autodesk.com/products/recap/overview (v.19.0.0.38 free educational version)

[4] The drone that was used is DJI Matrice 100.

[5] The software that was used is JPG Converter (v.5.0.101 - free use)

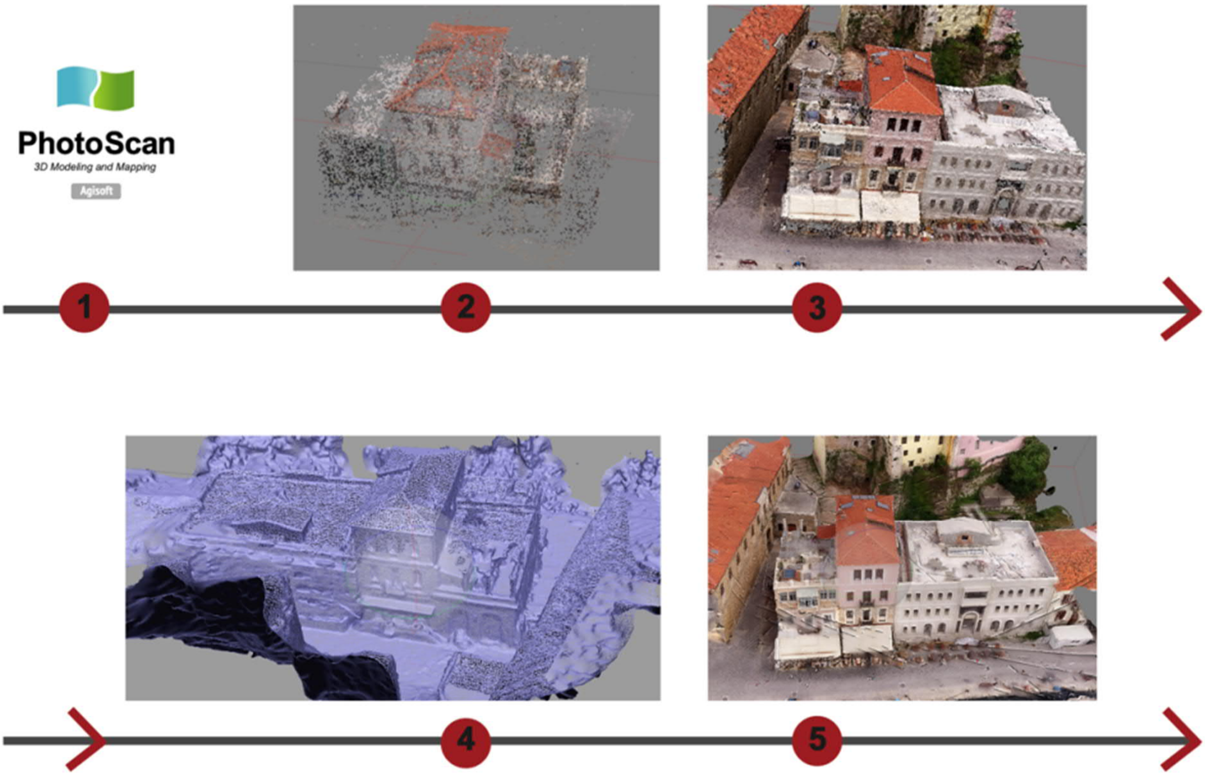

Fig. 1. Main implementation steps in Agisoft PhotoScan Professional. 1) Insertion of photographs, 2) 3D Point Cloud, 3) Dence 3D Point Cloud, 4) Mesh, 5) Final 3D model with Textures

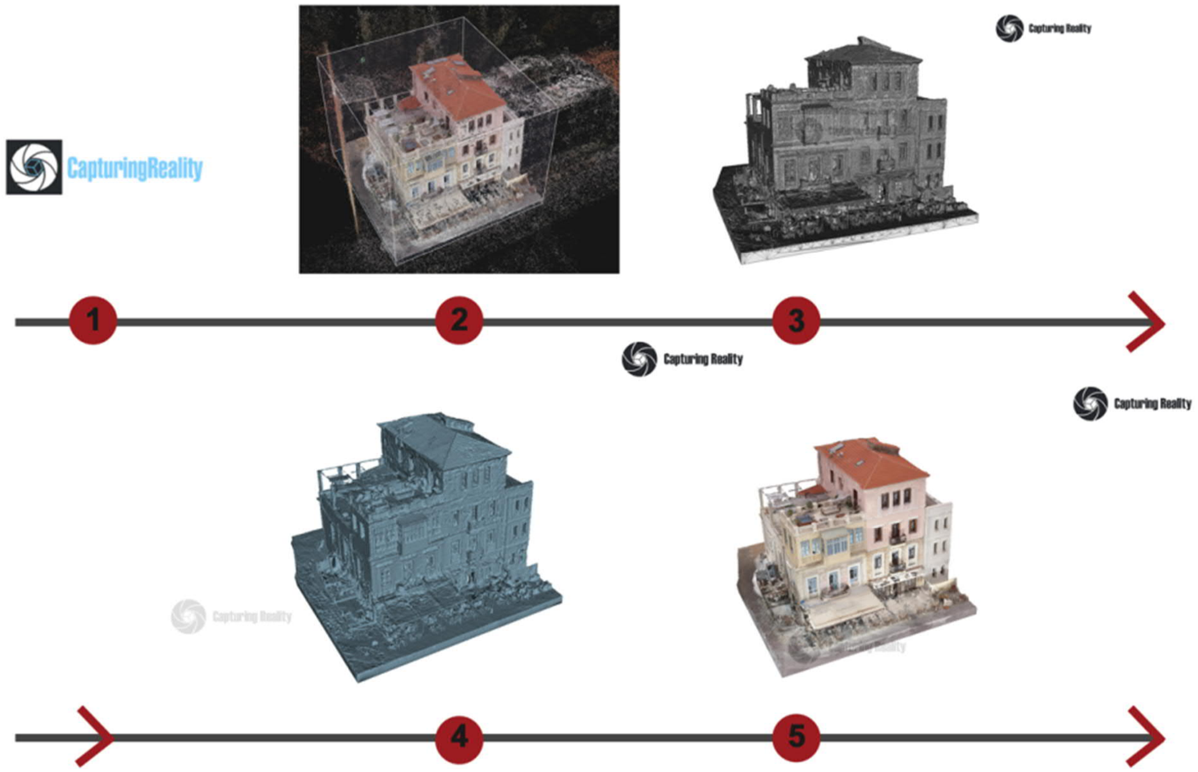

Fig. 2. Main implementation steps in RealityCapture. 1) Insertion of photographs, 2) 3D Point Cloud, 3) Mesh, 4) Solid 3D model without Textures, 5) Final 3D model with Textures

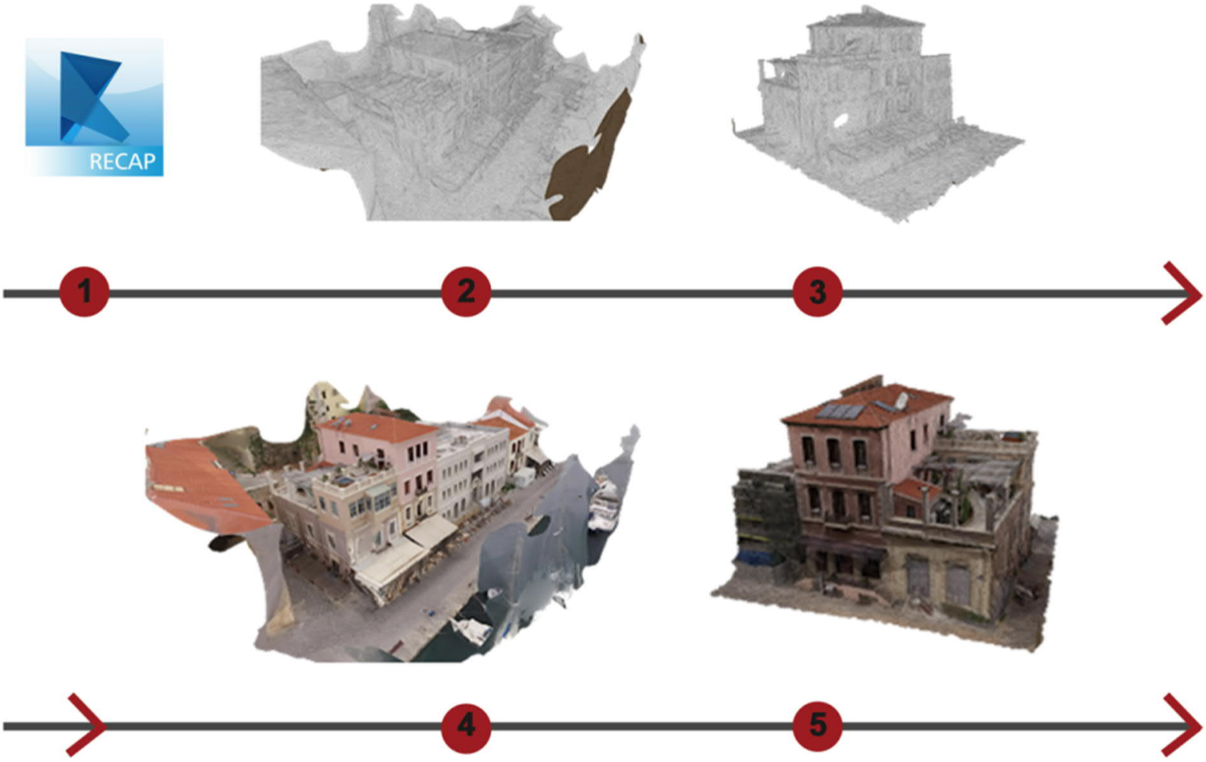

Fig. 3. Main implementation steps in Recap Photo. 1) Insertion of photographs, 2) Mesh, 3) Final 3D model with Textures and surrounding area, 5) Final 3D model with Textures

During the first attempt, the research team captured one building facade. Sixty-five (65) pictures were captured, inserted and processed by two distinct softwares, *Agisoft PhotoScan Professional*, and RealityCapture. The pictures had 42242 points each, with quality of image varying between 0.68-1.34 Agisoft Image Quality units, focal length 18 mm, and ISO 100. In *Agisoft PhotoScan Professional*, the steps and times that were needed were: Accuracy - Highest - 25 minutes, Build Dense Cloud - Medium - 30 minutes, Build Mesh - 15 minutes, Arbitrary, Dense Cloud, Height and Build Texture (Generic, Mosaic) - 15 minutes. The total time for the creation of the 3D model was approximately 90 minutes. The research team also created a video through *RealityCapture*. The main issues of the final model were a) the lack of pictures taken from different points that ended in lack of points at the final model and b) the fact that a percentage of the facade surface was covered with other objects (fabrics, pergolas, a/c inverters) that were equally translated as building elements into 3D point cloud and could not be isolated during the process.

During the second attempt, 267 pictures were taken from the three building facades, only from the ground level and inserted into *RealityCapture*. As a result, the model appeared slightly rotated from the horizontal level, and the ground level had to be corrected manually. The processing and settings time lasted approx. 60 minutes while the model creation lasted approx. 90 minutes. Many trials were conducted for the result optimization. The video exporting duration was approx. 60 minutes and the file size reached over 200 MB.

During the third attempt, the research team used a drone DJI Matrice 100[6] (Fig. 4), which flew for approx. 5-10 minutes, at small distance above the building with the camera inclined at 45 degrees. The drone path followed the building perimeter and then flew right above it, with the camera being vertical. The drone created two videos, lasting 194 seconds and 14 seconds. The video captured the hotel and the adjacent buildings, from an altitude of 15 meters for most of the time. As a result, the roof and the upper building level were well captured, while the lower levels did not appear properly.

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[6] Camera of the Drone: Zenmuse Z3. Characteristics: 1) Sensor: CMOS, 1/2.3" - Max Pixels: 12.76 M, Effective Pixels: 12.4 M, 2) Lens: 3.5x Optical Zoom, 22–77 mm Equivalent - F2.8 (Wide) - F5.2 (Tele), FOV 92° (Wide) - 35° (Tele), 3) Photo Resolutions: L(4:3): 12 M, 4000x3000 and L(16:9): 9 M, 4000x2250, 4) Video Resolutions: UHD: 4K (4096x2160) 24/25p - 4K (3840x2160) 24/25/30p.

Fig. 4. Drone DJI Matrice 100

Due to the fact that the video could not be directly inserted in the software for the 3D point cloud, the team used the JPG converter for the extraction of frames number/second from the two videos. 310 pictures were totally extracted in jpeg format, each of them occupying around 1.6 MB (resolution 4096 x 2160 pixels / 96 dpi / 24 bit).

The 310 pictures were inserted into *RealityCapture* and the time for the construction of the 3D model was 80 minutes. The outcome was satisfactory for the roof and upper parts of the facades, but not for the lower parts of them, compared to the previous model extracted from ground level shots. Many areas appeared with no details and deformed. For *Recap Photo*, 100 pictures out of the 310 were selected, mainly depending on their overlap percentage, good focus, etc. The uploading time of the pictures (total size 170 MB) on the Autodesk cloud was approx. 30 minutes. The model required approx. 50 minutes in order to be completed and available for downloading and further editing on the computer. On the model (rcm format, size 61 MB) some issues were encountered on the canvas and the blank parts were filled. However, the outcome was not satisfactory in comparison with the *RealityCapture* model (as was expected due to the use of only 100 out of the 310 pictures) but it showed the potential for further improvement considering the various editing tools and settings that the software offers. Finally, for the *Agisoft PhotoScan Professional*, 100 camera pictures (resolution 1920x1080) were selected, 29041 points with quality varying between 0.923 and 1.80 Agisoft Image Quality units. All steps conducted at ultra-high resolution, except from the dense cloud that conducted at high resolution. The editing time lasted 2 hours and 40 minutes, and the outcome was satisfactory for the roof and upper parts of the facades, with some minor issues at the building lower parts.

During the fourth and more holistic attempt, the research team combined the 310 drone pictures with the previous 267 pictures from the ground level. 577 pictures were used in total and were processed by two software, *Agisoft PhotoScan Professional*, and *RealityCapture*. In *RealityCapture*, in order to achieve a better matching of the different sets of pictures, 34 control points were used and the process lasted 7 hours. The outcome was improved due to combination of ground level and aerial pictures, and was superior to the result from *Agisoft PhotoScan Professional*, but still had quality issues.

Following to that, the research team created two separate models from the ground level pictures and the aerial ones correspondingly and combined the produced models with markers. 121 camera pictures were selected (resolution 1920x1080), and the model was completed in 3 hours and 20 minutes. Unfortunately, the result model was not satisfactory.

During the sixth attempt, 445 new pictures were taken and, along with 190 pictures from the drone, were inserted in *RealityCapture* (635 pictures in total), with their resolution between 8.8 MP (drone) to 13.5 MP. Due to the fact that different cameras were used and that pictures were taken on various dates, the software failed to combine the different parts into only one component initially. The research team implemented the matching by adding control points, which installed common points between different captures. After a long trial-error process that lasted 4 hours and the insertion of 90 control points in total, the point cloud component was completed, and after another 150 minutes the mesh was created. The outcome was radically optimized, as the number of pictures combined and the control points installed was the maximum of all previous attempts. (Fig. 5)

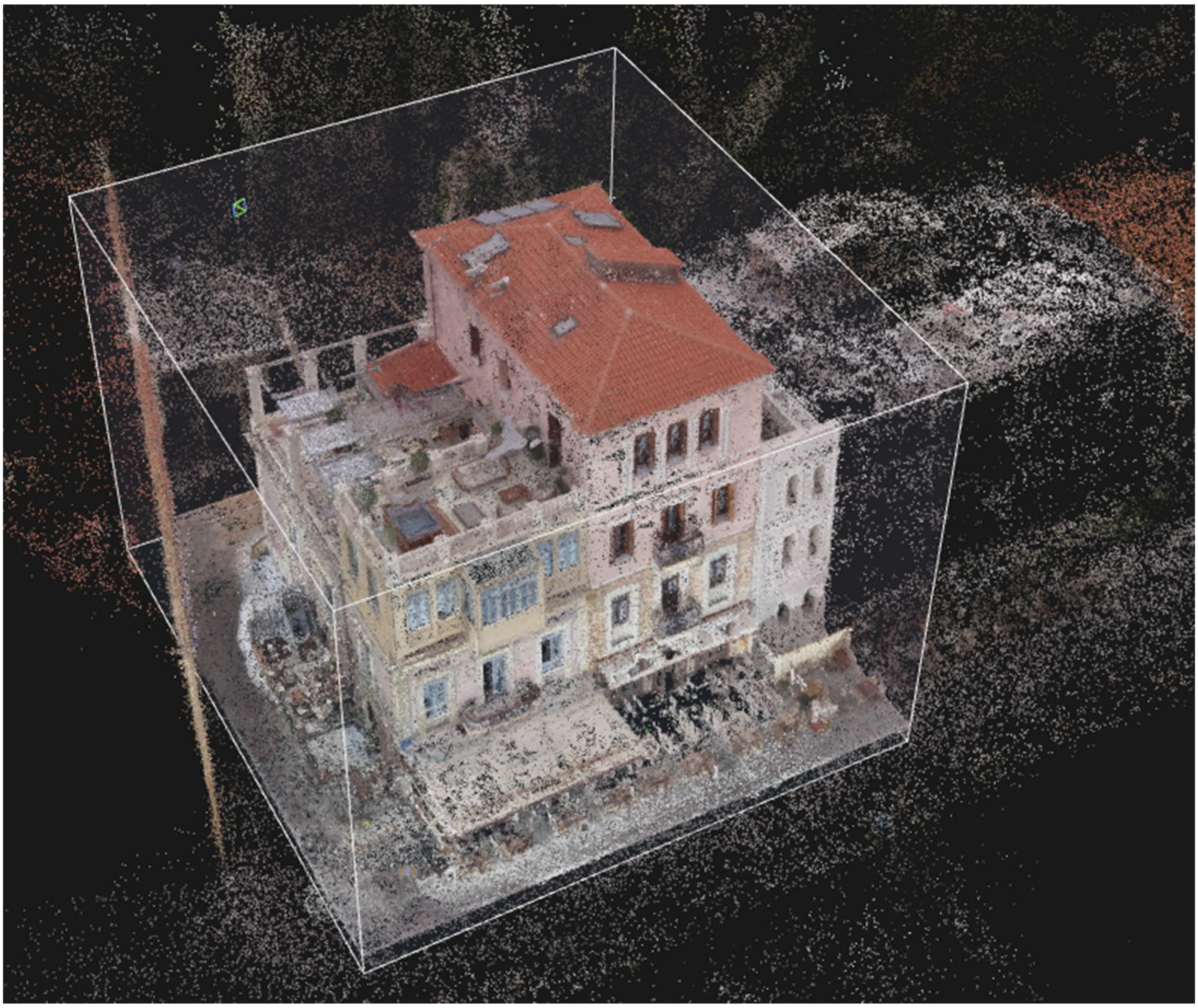

Fig. 5. 3D Point Cloud in Reality Capture

Finally, the research team made a last attempt with a 2-week-promo license Reality Capture, similar with the previous one, that used 631 pictures and 114 control points (Fig. 6). The time needed was 7 hours, and the outcome was adequate.

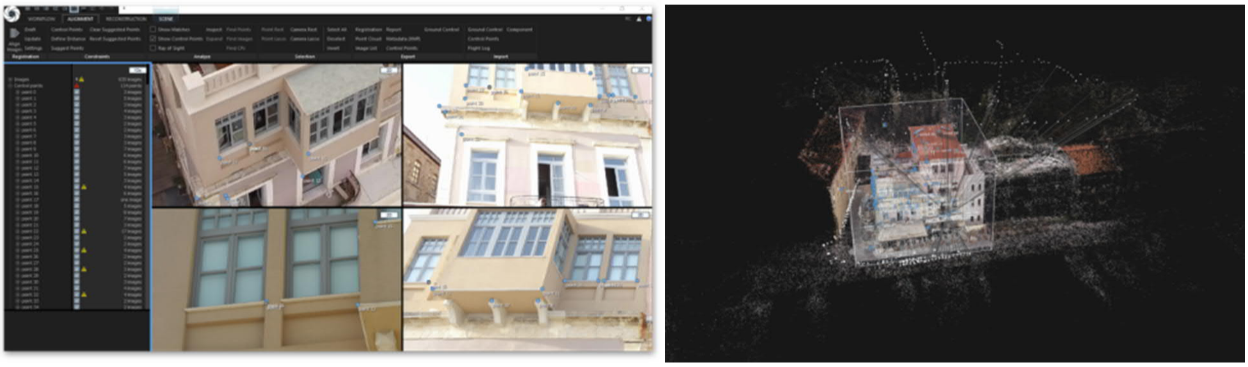

Fig. 6. Control points in RealityCapture

What is really interesting, here, is that the increase of control points did not improve the model, especially in the front facade that encountered the bigger issue.

Table 1. List of specifications of each attempt.

Number of Trials	**Camera/ drone**	**Number of pictures**	**SfM Software**	**Time of Process**	**Outcome**
1rst (one facade only)	Camera	65	*Agisoft PhotoScan Professional*	1 hour and 30 minutes	Not satisfactory, holes at areas that needed more pictures from different directions
			RealityCapture		
2nd (three facades)	Camera	267	*RealityCapture*	2 hours and 30 minutes (creation of video: 1 hour extra)	Not satisfactory, lack of pictures from high altitude
3rd (roof and three facades)	Drone DJI Matrice 100	310	*RealityCapture*	1 hour and 20 minutes	Satisfactory regarding the roof and facade upper parts Not satisfactory (compared to previous attempts) concerning the lower parts
		100	*Recap Photo*	2 hours	Not satisfactory in comparison to Reality Capture model Potential for further optimization
		100	*Agisoft PhotoScan Professional*	2 hours and 40 minutes	Satisfactory concerning the roof and upper parts of the facades / Issues regarding lower parts
4th (roof and three facades)	Drone DJI Matrice 100 and Camera	577 (310 and 267)	*RealityCapture*	7 hours	Improved model, due to combination of ground level and aerial pictures Improved in comparison with Agisoft PhotoScan Professional
			Agisoft PhotoScan Professional		
5th (roof and three facades)	Drone DJI Matrice 100 and Terrestrial pictures	121	*Agisoft PhotoScan Professional*	3 hours and 20 minutes	Not satisfactory
6th (roof and three facades)	Camera Drone DJI Matrice 100	635 (445 and 190)	*RealityCapture*	6 hours and 30 minutes	Radically improved model, due to extra pictures and control points
7th (roof and three facades)	Camera Drone DJI Matrice 100	631 (441 and 190)	*RealityCapture* (2-week-promo license)	7 hours	Satisfactory

Proposed 3D model improvement techniques

After seven attempts, the 3D model optimization technique was established to the following steps: 1) Usage of one high-resolution camera, with big sensor, good lens (prime, not zoom), and polarized filter (for the elimination of reflections from windows and glassy surfaces)[7], 2) picture overlapping at least 30 %, 3) picture capturing of the whole building besides the more focused ones, 4) picture capturing on cloudy days in order to avoid shadows and reflections, 5) picture capturing in the minimum time possible on the same day, in order to avoid position change of movable objects and shadow differentiation on each facade and finally 6) in the case of use of drone, camera specs should be finetuned (i.e. resolution, stabilizing system), pictures should be taken from a low level and should include as much building view as possible.

INDOOR POSITIONING SYSTEM (IPS) PROCESS

The second part of the research study presents the implementation process of an “Indoor Positioning System” (IPS) within the monument interior space, aiming to track user location within the building and record real-time visitor flows. The research team intended to create a digital building map providing the accurate location of each occupant who navigates into the building’s interior space via smart mobile phone device.

In this framework, the team used the indoor positioning platform Indoor Atlas and its component mapping application, Indoor Atlas Map Creator 2, which operates on Android OS.

Implementation Process Overview

The implementation process consisted of the following three steps (Fig.7): 1) The team signed up and uploaded floor plan images aligned with geo-coordinates on the world map to the link: https://app.indooratlas.com (setup), 2) users downloaded and installed on their mobile phones the Indoor Atlas Map Creator 2 application. Then they logged into the account and generated signal maps from collected data while they physically moved in the space (mapping). 3) The Software Development Kit (SDK) was generated.

The research team accomplished the above-mentioned process using the mobile device ‘Samsung S7 Edge’.

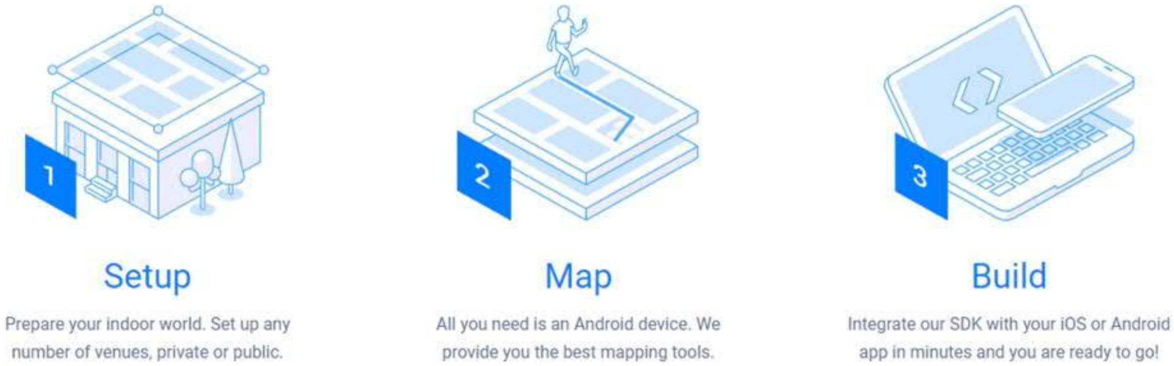

Fig. 7. Implementation steps (©IndoorAtlas)

Implementation Analysis

> *“The indoor positioning system (IPS) is composed of two components. The first processes the raw data from the inertial measurement unit (IMU), which ends up in relative position coordinates, which are passed to the second component. The second component transforms the relative coordinates into global ones and brings them into the context of the building”*
>
> [Bernoulli et al. 2010].

IPS technologies collect data using the smart device sensors from the surrounding environment such as magnetic, beacon, Wi-Fi etc. with the help of the user’s relative movement while moving physically into the space. The selected data are then compared against digital maps, which have been produced by algorithms on Indoor Atlas

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[7] A camera should have at least an 1 inch sensor or preferably an APS-C sensor and high resolution (e.g. about 24 MP). With a larger sensor area it's much easier to capture detailed images under any light conditions and avoid any loss of quality. Wide angle (e.g. 24 mm) and fast (e.g. f2) lenses will allow more light capturing and combined with a stabilization system will contribute in blurry images avoidance. A camera with 4 K video capabilities will be very convenient in extracting high quality images from the video.

cloud platform so as to obtain user's location. The best location accuracy can be achieved when more data have been observed [IndoorAtlas 2019a]. After several tests and detailed recording of the steps and the constraints presented during the implementation of the mapping application, the research group achieved the creation of a digital building map for two levels of the hotel accommodation. Below, these main constraints and therefore key points of attention are gradually presented.

1. Floor plan alignment with geo-coordinates

The main requirement of the setup step is the alignment of the building satellite image with the correspondent vector plan. However, the map provider isn't always able to show accurate photos of the case study building as in some geographic regions satellite images have low quality or insufficient details. If building's outlines are not clear, the floor plan alignment risks to be imported inaccurately and at a wrong scale [IndoorAtlas 2019b]. If the satellite view does not provide enough details to accurately align the image, the "Exact coordinates" alignment method can be used to achieve maximum superimposition of the two maps [IndoorAtlas 2019b].

Another significant factor is the simultaneous uploading and alignment in case of multiple floor plans of the study space. In this case, floor plans must be meticulously uploaded with the same and correct alignment, paying particular attention to elevators, staircases and escalators, so as to achieve smooth and easy floor transitions. It is equally important to provide the “Floor Number” when the building has multiple levels as the correct floor number determines the exact superimposition of various levels.

2. Hardware requirements and settings

The devices' requirements for creating a digital map according to the official website are: a) Android software and OS version 5.0 or newer and b) Hardware sensors (accelerometer, magnetometer, gyroscope). The list of devices that are able to accomplish the mapping process is narrower than the one suitable for the positioning.

On the other hand, for the positioning mode, Indoor Atlas SDK can run on both android devices which support API level 21 (Lollipop) and on iPhone 4S or newer models. Indoor Atlas automatically uses all available sensors to provide the best possible positioning experience, but for the most accurate one, gyroscope and magnetometer are needed [IndoorAtlas 2019c].

Another crucial point is that the Wi-Fi scanning features in the device settings must be enabled and have a strong signal, otherwise the recorded paths are not optimal and the resulting map quality is affected.

Low Wi-Fi scanning quality or frequency, which varies across phone models [IndoorAtlas 2019d] lead to continuous MapCreator warnings pop-ups on the device's screen that hinder the mapping process and demand more time mapping on the same areas to achieve satisfying performance [IndoorAtlas 2019d]. In order to ensure that the scaling was right, the distance between two waypoints was measured with the use of MapCreator2, during the Mapping Process.

3. Mapping Process (Fig. 8)

The mapping process requires the digital juxtaposition of the two-dimensional drawing with the global coordinates. The key points for this alignment are called waypoints and are identified by manually tapping on the digital map while standing at the physical space corresponding point. The most important part proved to be the correct alignment of the first waypoint. According to Eric Piehl

> *“After the first fix is computed, the heavy-duty algorithms kick in and very accurate positioning estimates are calculated using the geomagnetic and other methods.”*
>
> [Piehl 2018]

During the mapping process, the following errors occurred: 1) some waypoints were placed at inaccessible physical spots. As a result, the user was not able to recognize them with accuracy when proceeding to checking in that points, or run out of time because there is a five-minute time limit while recording a path, 2) pop-ups appeared on the device's screen warning on the fact that the compass heading didn't match the path. Positioning the phone face up during the whole mapping process solved the issue. According to the software developers *“if such a path is stored, the resulting map quality will be low and thus likely leads to red mapping analytics and inaccurate positioning.”* [IndoorAtlas 2019d] 3) it proved difficult to achieve an accurate location positioning of the user after the first mapping within the building. As recommended in official Indoor Atlas support solutions webpage [IndoorAtlas 2019d] an ideal Wi-Fi mapping coverage cannot be achieved with the recording of a single pass through a bigger space or even a corridor. Especially in wider spaces it is recommended parallel paths to be recorded in order to achieve the best geomagnetic coverage. (Fig. 9)

Fig. 8. Mapping process a) insertion of waypoints; b) creation of path; c) creation of digital map

Fig. 9. 'Magnetic mapping coverage' map

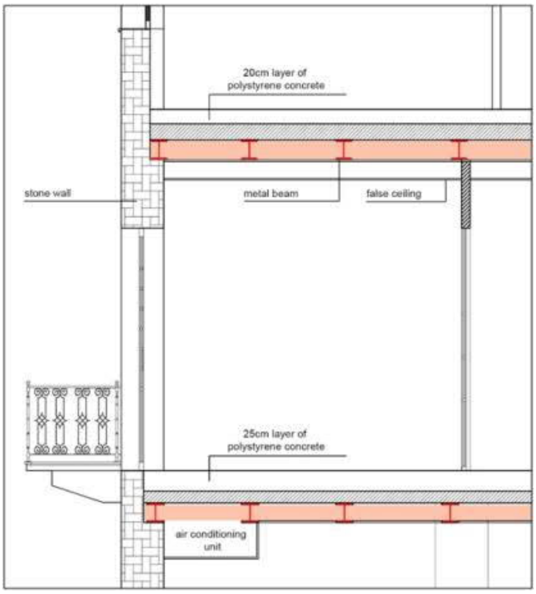

Fig. 10. Case Study Building Section, scale 1:50

4. Building structure

The building structure also played a key role in the mapping in terms of materiality. The material that has the ability to interact with the magnetic field of the earth and create a unique magnetic landscape is steel. However, the walls of the specific building are stone-built. The research team conducted an analysis of the structure prior to the experiment implementation to reassure that the mapping attempt would be successful. It was proved that during the building restoration and reuse as a hotel, metal beams covered by false ceilings were used for the reinforcement as shown in the image (Fig. 10).

According to the study, important elements that contribute to the mapping process in the building are lifts. In addition to the metallic elements contained in the lift, another factor that can contribute is the barometric pressure resulting from the change of level. The barometer sensor of a smartphone can detect even the smallest changes in atmospheric pressure, which is modified whenever the user moves in a vertical direction (via a lift or a ladder).

COMBINATION OF THE TWO METHODS

This case study was used to allow the establishment of a new spatial framework where the two methods will interrelate, influencing and feeding into each other. On the one hand, SfM is an already applied photogrammetry method producing imagery using low-cost metric cameras and aims at the sparse reconstruction of the building's point cloud model [Hopkins Nyimbili 2016]. On the other hand, the Indoor Positioning System is a new method, currently in beta version, that produces Human - Building Interaction quantitative data and tracks in real time the users' location within the building. SfM produces geometry through scanning, while IPS uses Internet of Things to extract informational data of the building. While both methods are developing technologies and none has reached its full potential, they remain completely different, both in terms of their operational process and the outcomes. Their only common point is that they both relate to the geometrical attributes of the building and extract information on it. We argue that the SfM produces form, while IPS deciphers the function of the building.

What is the optimal way to combine these two methods into a common spatial framework? And how would this combination contribute to the establishment of the building-as-a-service model? The integration of the two methods into a novel three-dimensional space can be executed in a twofold way. Firstly, as a means of integrating building function into form. In that framework, the relative user position and movement paths extracted by the multiple two-dimensional IPS layers can be geo-referenced with the 3D point cloud model created by the SfM method. What is necessary, here, is the development of new BIM libraries in order to take into consideration the level of detail required and the simplification of the models.

> *"The BIM offers a distinctive factor, which does not exist in any other field: a multi-layered spatial character in the third or even fourth dimension, when historic phases of the building are considered. These 3D models must allow a continuous transition in scale between the survey of the whole architectural complex and its individual elements."*
>
> [Rodríguez-Moreno et al. 2016]

Secondly, as a means of enhancing the user experience within the building, through the combination of the two methods with VR applications. Given that user location is trackable through the use of smartphones, IPS applications are able to calculate the building occupancy, densities and flows real-time. At the same time, the geometry of user flows can be referenced within the same axis system of the SfM model. Combining the above, we could envision a VR environment, where the user would be able to virtually visit the building's best or most populated spots, and experience the space at different moments of its life.

CONCLUSIONS

In this study, an approach to experiment and combine SfM and IPS methods in the current state-of-the-art architectural technologies is demonstrated on the monument of Ambassador's Residence in Chania, Crete. The usefulness and limitations of the methods are presented in the two experiments. The contribution of the current study consists in overpassing the operational application limits of the existing technologies and trying to juxtapose a 'relative, image-space coordinate system' into a 'real-world, object-space coordinate system'. However, the two technologies have significant limitations, such as the need for multiple cameras in the case of SfM, or the use of specific Android Smartphones for the building mapping in the case of IPS. In future studies, it is important to experiment with the application of a building-as-a-service model that will function as a knowledge container of the building and as an innovative platform for future VR applications.

REFERENCES

Thomas Bernoulli et al. 2010. Infrastructureless Indoor Positioning System for First Responders, Proceedings of the 7th International ISCRAM Conference – Seattle, USA.

Penjani Hopkins Nyimbili et al. 2016. Structure from Motion (SfM) – Approaches and Applications, Proceeding of the International Scientific Conference on Applied Sciences: "Spatial Data Processing, Modelling, Analysing and Management for Knowledge Based Systems", Antalya, Turkey.

Francesco Gabellone. 2009. Ancient contexts and virtual reality: From reconstructive study to the construction of knowledge models. Journal of Cultural Heritage, (10), 112-117.

Indoor Atlas. 2019a. Positioning Technology. Retrieved January 8, 2019 from https://www.indooratlas.com/positioning-technology/

Indoor Atlas. 2019b. Mapping Solutions. Retrieved January 8, 2019 from https://indooratlas.freshdesk.com/support/solutions/articles/36000035916-why-can-t-i-see-the-details-of-my-building-in-the-satellite-view-of-the-web-tool-

Indoor Atlas. 2019c. Devices Compatible with Fingerprinting: Support. Retrieved January 8, 2019 from https://indooratlas.freshdesk.com/support/solutions/articles/36000054947-supported-devices-for-fingerprinting

Indoor Atlas. 2019d. Map Creator Warnings: Support. Retrieved January 8, 2019 from https://indooratlas.freshdesk.com/support/solutions/articles/36000050512-mapcreator-warnings

Eric Piehl. 2018. Mapping the unmappable'. Retrieved January 3, 2019 from https://www.indooratlas.com/2018/12/12/mapping-the-unmappable-how-we-enabled-positioning-at-the-redi-shopping-mall-in-less-than-8-hours/

Concepción Rodríguez-Moreno et al. 2016. From point cloud to BIM: An integrated workflow for documentation, research and modelling of architectural heritage, Survey Review, DOI: 10.1080/00396265.2016.1259719

Imprint:
Proceedings of the 23rd International Conference on Cultural Heritage and New Technologies 2018.
CHNT 23, 2018 (Vienna 2019). http://www.chnt.at/proceedings-chnt-23/
ISBN 978-3-200-06576-5

Editor/Publisher: Museen der Stadt Wien – Stadtarchäologie
Editorial Team: Wolfgang Börner, Susanne Uhlirz