AN AS-BUILT ON-LINE MODELING TECHNIQUE : AOMS

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ABSTRACT:

In the first part of this paper, we will describe some recent applications of photogrammetry in industry. We will focus more specifically on one project requiring both 3D as-built modeling and 3D high accuracy measurement. We will describe the measurement methodology and the results.
On the second part of this paper we will present some recent developments carried out with the idea of automating as much as possible the image processing.

1. INTRODUCTION

Over the past fifteen years photogrammetry has been successfully introduced in industry especially for the 3D CAD modeling of industrial installations and for the 3D high accuracy measurement of large components, on site. This increase in the use of photogrammetry is mainly due to the advent of digital cameras and semi-automated image processing softwares.
Some applications carried out recently are a good illustration.

2. REVIEW OF SEVERAL APPLICATIONS

2.1 Measurement into thermal chamber

To determine the deformations of a satellite under different thermal conditions has always been a challenge. Digital photogrammetry is certainly the first 3D measurement technique allowing the measurement of such deformations with a very high accuracy.

In 1998, ESIC and INTESPACE developed a testing method with the intention of increasing as much as possible the accuracy. The idea was to be able to measure an object placed inside a thermal chamber, at different temperatures between –135°C and + 110°C. Two strategies were possible:

- to measure the object turning on a rotating table with the camera outside looking through a glass plate (see figure 1: INCA camera outside the chamber),
- to measure the fixed object with the camera inside the thermal chamber and protected by a canister, moving around the object.

After some investigation it was founded that the two solutions were eqivalent providing that for the solution with the camera outside, the glass plate is of optical quality and allows a good view of the object. In both cases the biggest challenge is to keep something invariable during all the test to get some scale information: for this reason a thermostable jig was developed with targeted points giving the same scale regardless of temperature.

Another loss of accuracy is due to the fact that this reference jig is measured twice, i.e. once for each stage, and the comparison between two stages is affected by the combined accuracy of the two separated measurements. To decrease this effect, all the observations of the reference jig from both stages are computed together in the final bundle: this allows an increase of the accuracy and detection of any local deformation of the jig.
With this testing method an accuracy of ± 30 µm was reached on the measurement of a 2.5 m diameter antenna, with a film based camera CRC2 from GSI (medium format: 12 cm x 12 cm).
Nowadays, first experiences with digital cameras are indicating an achievable absolute accuracy of about ± 50 µm.

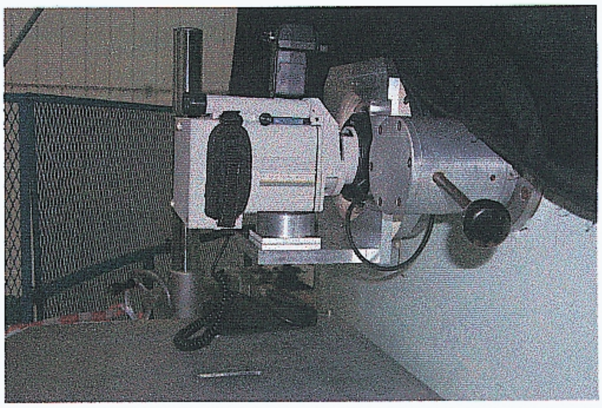


Figure 1: INCA camera outside the chamber

2.2 A measurement fully integrated into an industrial process

The most convincing proof of the acceptance of photogrammetry in industry is when photogrammetry is part of an existing and recurrent industrial process.
This is the case in a French nuclear plant where ESIC SN is responsible for the measurement of all the control rods before closure of the bulkhead, at the end of every maintenance shut down (see Figure 2: view of the control rods).

The measurement consists in checking the position of the top of about 50 control rods with respect to the corresponding holes on the bulkhead. 18 images are taken from different positions all around and are processed in few minutes.

This measurement has already been done about thirty times and is now an integral part of the process.
The analysis of the measurement highlights trends allowing the prediction of the evolution and implementation of modifications before any problem occurs (See Figure 3: analysis).

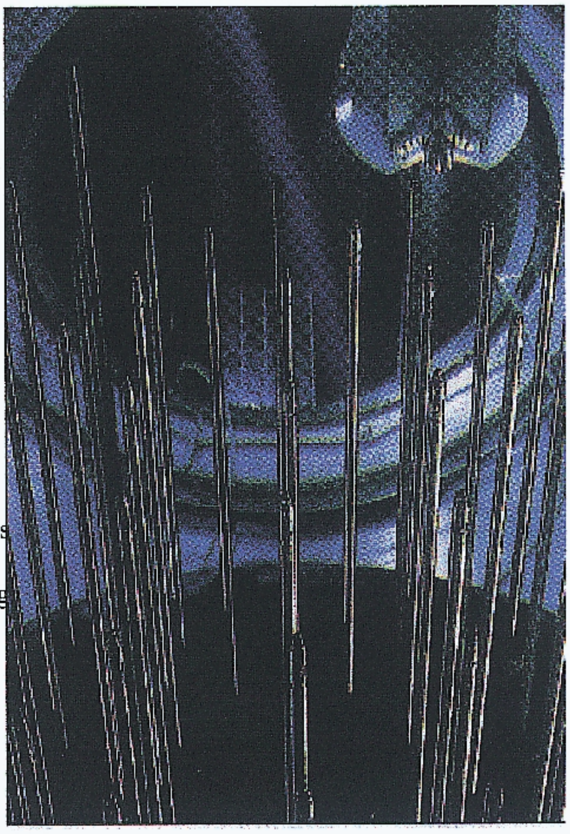
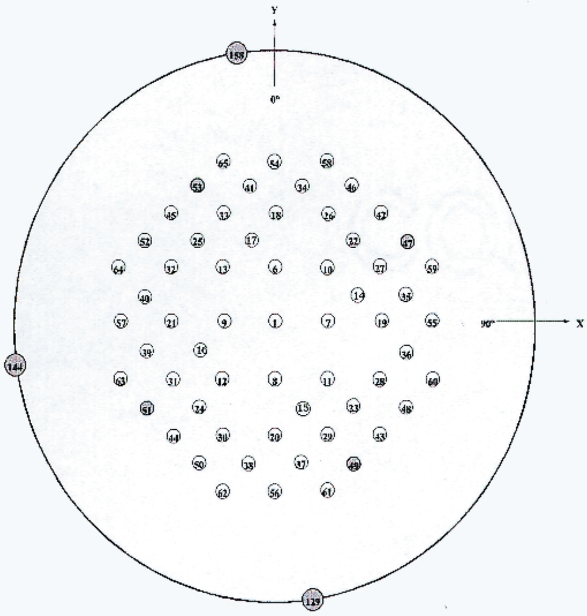


Figure 2: view of the control rods



No	THEORIQUE X1	THEORIQUE Y1	MESURE X2	MESURE Y2	dX	dY	dXY
1	0	0	-6	5	-6	5	8
6	0	430	-6	427	-6	-3	7
7	430	0	391	-29	-39	-29	48(1)
8	0	-430	2	-430	2	0	2
9	-430	0	-426	4	4	4	5
10	430	430	447	430	16	0	16
11	430	-430	433	-450	3	-20	20
12	-430	-430	-453	-450	-23	-20	30
13	-430	430	-432	417	-2	-13	13
18	0	860	32	859	32	-1	32
19	860	0	852	6	-8	6	10
20	0	-860	14	-865	14	-5	15
21	-860	0	-884	-29	-23	-29	38(1)
22	645	645	645	643	0	-2	2
23	645	-645	618	-686	-27	-40	48(1)
24	-645	-645	-623	-628	22	17	28
25	-645	645	-614	655	31	10	33

Figure 3: analysis

2.3 When the requirement is both 3D modeling and 3D high accuracy control

In 1999, ESIC SN has been involved in a big maintenance and modification project of a nuclear cell of the plant of LA HAGUE, for the company COGEMA. The objective was twofold: to provide a full 3D AS-BUILT CAD model of the cell for the preparation / simulation of the operation (see figure 4 : 3d as-built model) and to provide locally a 3D high accuracy control of the mechanical interfaces of equipment that had to be removed.

This cell was part of the few hundred cells covered by a photogrammetrical survey between 1989 and 1994, at the end of construction phases. The 3D model has been generated from about 600 photos.

The 3D high accuracy measurement needed to be repeated because an accuracy of only 5 mm could be achieved by processing the old photos. Also components could have moved during the years and during the removing of the old equipment. For this measurement a tube camera, used by COGEMA for vision purposes was used, in a completely remote controlled way. The processing of about ten images with targeted points gave an accuracy of about ± 1 mm which corresponded to the requirements.

This application showed that the longest steps of a photogrammetric measurement are both targetting and image processing. To work on these two aspects it was decided with COGEMA to investigate some detection tools that could be implemented on the image processing, allowing the possibility of targetless measurement and automated image processing.

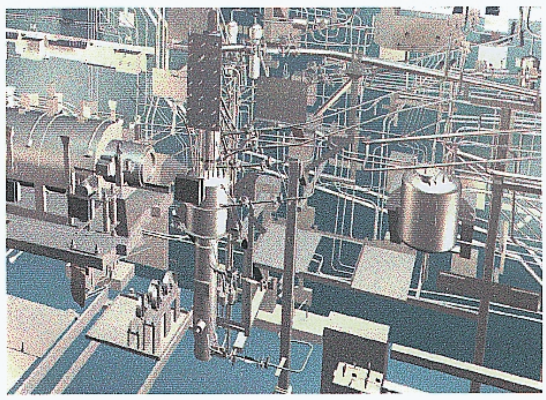


Figure 4: 3D as-built model

These developments are based upon a basic statement which is certainly the origin of the successful development of photogrammetry: images of an object contain all the necessary information for the 3D modeling of this object ; it's only a matter of developing tools to automatically search for the information, instead of asking an operator. Some of these tools already exist but are rarely used by photogrammetrists. Therefore the approach of the research and development project is to link image processing tools and photogrammetric techniques.

3. AOMS: A RESEARCH AND DEVELOPEMENT PROJECT

3.1 The aims of AOMS

The major aim of the developments carried out in AOMS is to reduce the time involved for 3D as-built modeling. AOMS is dedicated to the 3D modeling of industrial installations.
As mentioned above, many photogrammetric systems are available which use the operators skill to detect and to identify any points or features on the images. With such systems, image analysis is time-consuming and very often needs targets on the object. The basic approach of AOMS is to develop some automatic image processing tools, which allow real-time (on site) preparation of a 3d as-built model, without adding anything to the installation.

3.2 Presentation of AOMS

From images, AOMS can measure points or other 3D primitives like lines, cylinders, circles, or specific industrial primitives like " U beam "... At least two images of the object are needed but the system is working in a multi-images mode, allowing the accuracy to be increased if needed.
Ideally, the process is based upon the use of two calibrated cameras mounted on a bench: internal parameters of each camera and their relative positions and orientations should be known (by doing a calibration). This way, scale information is provided (distance between the two cameras) and a first triangulation is immediately possible, giving approximate values for computation.

AOMS is for the moment a semi-automatic tool. The operator has to choose the kind of primitive and to select it by clicking between two and four times. After that, the primitive is accurately modelized. Using more images, the 3D model is improved and completed. With the help of this real-time model, the operator can check its completeness and interact with the acquisition process.

3.3 Case study

A test has been carried out by measuring an experimental installation of about 6 m^3: figure 5 shows part of the installation.

A reference model was established using a KODAK DCS 460 camera (2036x3060 pixels), using targets, taking 40 images and processing data with existing photogrammetric softwares. The accuracy achieved is about 1 mm on the 3d positioning of pipes and 0.15 mm on their radius. An AOMS model has been established using two very low resolution camera (765x512 pixels), taking 20 images and processing the data with AOMS. 9 pipes with radii between 6.8 mm and 348.7 mm were modeled (see figure 6 : reference model and AOMS model).

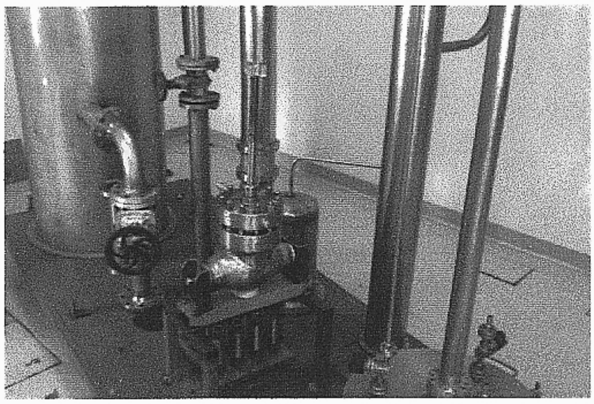
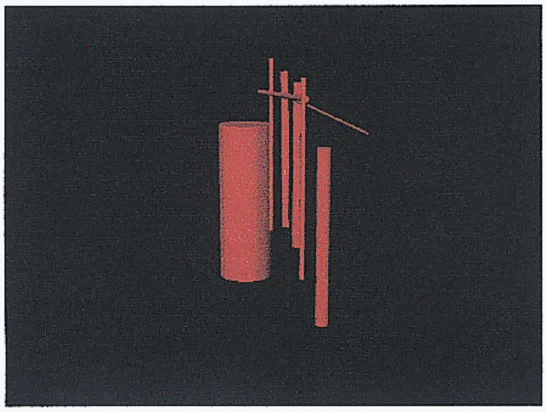


Figure 5: part of the installation

The comparison made between the two models is given below ; the analysis is based upon distances measurement between all the pipes and a reference pipe, upon orientation and radius of each pipe.

	Distance error (mm)	Orientation error (deg)	Radius error (mm)
RMS	5.1	0.2	0.3

This test shows that a standard camera used with photogrammetric software including image processing tools can give a 3D model with a sufficient accuracy for many applications. Moreover, this 3D model can be partially produced on site for immediate use or for checking its completeness.



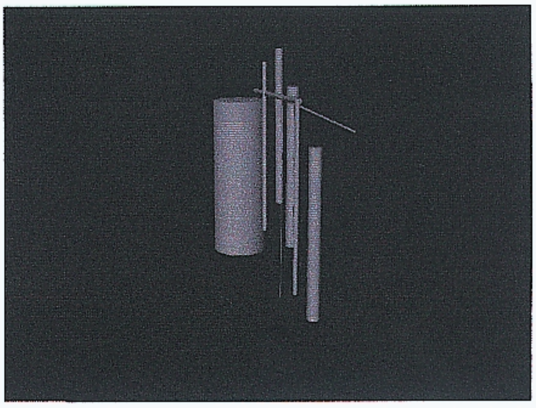


Figure 6: **reference model** **AOMS model**

3.4 Case on site or realworld application

We present here two applications conducted on real industrial installations. The aim is to test AOMS in a real-world situation and to compare results with the results of existing photogrammetric packages.

3.4.1 3D modeling project

The aim was to extract measurements and to generate a 3D CAD model from photos.
For the test, the field survey covered an area of about 3m x 1m x 0.4 m. Fourteen high resolution (5000x4000 pixels) images were used. We obtained two models: the model created with an existing photogrammetric software (MonoPlantgen) and the final AOMS model. The comparison, concerning the time required for the elaboration of these models and their precision, is summarized in the following table.

	Reference model	Final AOMS model
Time	6 hours	4 hours
Radius error (mm) (RMS)		3.2
Position error (mm) (RMS)	10	11.3

Figure n°7 shows the superimposition of the two models.

As a first approach, time is reduced by 33% and the estimated accuracy is the same.
Taking into account that for this application only old stereoscopic photos were processed, it is realistic to expect a better accuracy in case of a completely new project.

3.4.2 High accuracy measurement

Photogrammetry is used in this case to determine the geometry of pipe installation (see figure 8: example of installation), which need to be replaced in a nuclear power plant. This advance knowledge will allow fabrication of the new pipings to be performed during operational time rather than during expensive downtime and will also allow the fit of the new pipes to be assessed.

Because of the radioactivity of the area, the survey was carried out using a vidicon CAMERA EGG HEIMANN KH500. It is important to note that this is not a high performance sensor for photogrammetry: low resolution and noisy images. Twenty eight images were taken with this sensor using a 8 mm focal lens.

A comparison has been made between two 3D models (see next table).
To create the first model, existing software (SCANTOUR from ESIC SN for targetless points and V-STAR from GSI for targetted points) were used and a specific object with topographic targets was introduced into the installation in order to provide the required accuracy.
The second model was made with AOMS. The objective was to prove the feasibility of high accuracy measurement without adding anything to the installation.

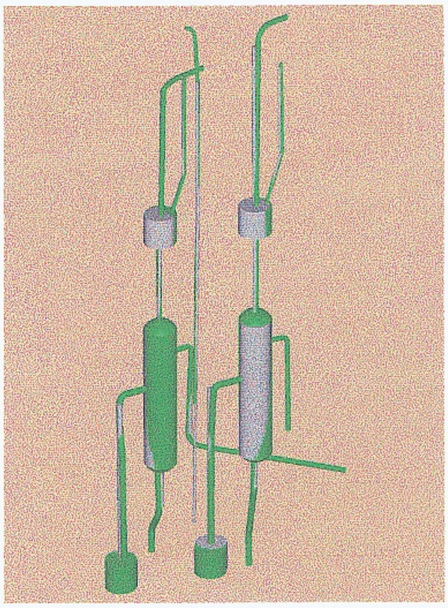


Figure n°7: superimposition of the two models

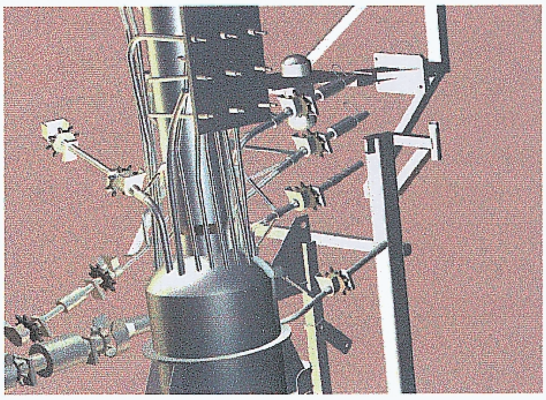


Figure 8: example of installation

	Model with existing software	Model with AOMS
Time	8 hours	3 hours
Radius error (mm) (RMS)	(Standard radius values as input)	1.3
Position error (mm) (RMS)	3	8.7

It's important to note that, with existing softwares, the accuracy is 5 times worse without targets. With AOMS, as a first approach this factor is only 3: the objective is to get close to 1.

3.5 Perspectives

- AOMS is still a research and development project. So far a lot of work has been done on features detection. The aim is to be able to process about 50 images per day.
- The next stage of research is to develop automated feature and tie point matching tools. With this automated image matching capability, the tool will reduce the labour for photogrammetric processing and it should be able to process about 80 images per day.
- AOMS is made for on site results. It allows not only a much shorter processing time for images but also better control over the measurement process because it provides the CAD model on site.