MEASUREMENT IN HAZARDOUS ENVIRONMENT : REVIEW OF SEVERAL APPLICATIONS

Arnaud DUMONT - Technical Manager

ESIC France - Working Group WG V/3 - Structural and Industrial Measurements with Consideration of CAD/CAM aspects

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ABSTRACT

How can we carry on three-dimensional measurements where the level of radioactivity is high ? and underwater ? and into a thermal chamber ?
Such questions have recently found an impressive answer, mainly through the technique of digital photogrammetry.
In this paper, we will discuss about applications done in each of the items mentioned above. The accent will be put on the industrialization of the process and on the CAD/CAM aspects.

RESUME

Comment réaliser des mesures tridimensionnelles lorsque le taux de radioactivité est élevé, sous l'eau ou dans une chambre thermique ?
Une impressionnante réponse a récemment été apportée à ces interrogations et notamment par le biais de la technique de la photogrammétrie digitale.
Ce document se propose de présenter les différentes applications réalisées dans chacun des cas de figure cités ci-dessus. L'accent sera notamment mis sur l'industrialisation du procédé et sur les aspects concernant la CAO/DAO.

1. THE ORIGIN

First of all we have to define what we call hazardous environment and what kind of measurement we need to carry on.

An easy way to imagine what we call an hazardous environment is to say that it's a place where noone should go ! In practice, someone, in some of them, could go but not for a long time or with big difficulties.
This definition clearly concerns :

- nuclear environment,
- underwater,
- thermal chambers,
- vacuum chambers,
- pit for pressure test,
- etc...

But what kind of measurement is required in such areas ?
We have to distinguish two purposes : <u>the first one</u> is for <u>maintenance</u> ; for example when an equipment has to be changed or when an incident occurs. One of the traditional methods consists in building a jig even with the possibility of mechanical measurements. This costs a lot, is not very fast and not accurate at all. It's mainly the case of nuclear and underwater environments.
<u>The second purpose</u> is for <u>testing</u> ; for example, when an equipment has to be tested under thermal or vacuum conditions or when the dimensional information has to be related to a pressure value. We are speaking for example of thermal or vacuum chambers or pits for pressure tests.

Hazardous environment, maintenance or test purposes, needs of dimensional information ; the scenery is ready : let the actors in (we should say out !).
Basically, the idea is to use a CCD sensor which allows mainly two things :

- to penetrate an hazardous environment (with or without protection),
- to check the data in real time and to have the results quickly.

Therefore, the use of a CCD sensor determines the study of the following aspects :

- first is what could be called <u>the «hard»</u> and will mainly concern the sensor, its canister and the separating glass,
- second is <u>the «methodology»</u> for data capture,
- third is what could be called <u>the «soft»</u> and will mainly concern the way to process the data.

2. THE SOLUTIONS

2.1 Solutions for hard

The development of the technique of 3D measurement using digital photogrammetry is the main factor that made applications easier. In fact, some successful experiences have been carried out over the last ten years, using the technique of film-based photogrammetry but big restraints remained, mainly :

- validation of data capture only at the end,
- long time for data processing.

CCD sensors, once the reachable accuracy has been sufficient, appeared as the solution : the user can immediately check the images and can get the results very quickly.
CCD sensors available were at first such cameras as the KODAK MEGAPLUS with 1.4 millions pixels and now 4.2 and even 6.3. Practically, this means that the resolution of the sensor is an old problem and future improvements will be more pertinent on other sides.
Canisters are available today especially because of the development of vision applications. The only problem is the optical quality of the glass and the isolation. Good results can be reached with an optical quality of $\lambda/4$ and the isolation can be solved for example with a water-cooling system for a thermal consideration or a lead protection for a nuclear consideration.

2.2 Solutions for methodology

The range of applications that ESIC has recently solved leads to distinguish two types of applications :

- concerning the mutual positioning sensor/object : object fixed and sensor moving or object moving and sensor fixed,
- concerning data capture and processing : stereoscopic configuration or monoscopic configuration.

Concerning the mutual positioning sensor/object, both cases (object fixed and sensor moving or object moving and sensor fixed) have advantages and drawbacks. From our experience, the most accurate is the first one, object fixed and sensor moving because :

- there is no possible object deformation,
- there is a big degree of freedom to optimize the geometrical configuration.

On the other hand, it is more complicate to move the camera than to put the object on a rotating table.
So each case has to be thought knowing that the required accuracy will mainly decide.

The other aspect of the methodology is the distinction between the stereoscopic and the monoscopic configuration. Here the mainly criteria are :

- the required accuracy (stereoscopic configuration being less accurate),
- the possibility of putting targets or not on the object.

The possibility of putting targets or not has to be considered more in detail. In fact, the stereoscopic approach had been used many times and had given quite good results. But we have now to distinguish the surfaces on which no «natural point» can be well defined and the surfaces on which some «natural points» as holes or edges of planes can be well identified ; in such a case, the convergent approach can still be used with the only effect of loosing accuracy.

2.3 Solutions for soft

Solutions for soft are concentrated on the influence of two components :

- the separating glass,
- the object medium.

Here the purpose is to reach the sufficient accuracy, knowing that, in case of bad accuracy required, many things can be neglected. Good accuracy today, while waiting for new developments, can be reached with some artifice ; the most interesting one is to put a known object into the scene which allows to modelize the corrections for all the xy measured coordinates on the image.

3. RADIOACTIVITY

In a nuclear environment, requirements turn mainly around :

- interchangeability,
- as-built model for maintenance or dismantling.

ESIC carried out its first measurement in such an area in 1992 with the prototype of the V-STARS (GSI : Geodetic Services Incorporation) system (see figure 1). The sensor used at that time was a KODAK MEGAPLUS camera of 1.4 millions pixels and the aim of the measurement was to define the positions of interfaces of an equipment that has to be put into a radioactive cell.
The limits found at that time were :

- in terms of radioactivity : 10^4 rad/hour,
- in terms of accuracy : $\pm$ 0,2 mm
  (for a volume of 2m x 2m x 2m)

Such results opened the way for accurate measurements in radioactive areas.
One particularity that has to be mentioned is that, to decrease the level of radioactivity for the sensor, a mirror (45°) was implemented in front of the camera.
Final results of these kinds of measurements, depending on the way that images are processed, can be : either a numerical 3D analysis for interchangeability, or a complete 3D as-built model (see figure 1.2) with as-built drawings, or drawings for manufacturing.

4. UNDERWATER

When the requirements, in terms of accuracy, are very high, underwater measurement seems to be the most complicated job. Water has to be clean and stable, lightening requires good experience and data have to be processed taking into account the optical deviations. But, once all this is done, many measurements are possible.
One example carried out by ESIC is concerning the measurement of rails and of a carrier interface (see figure 2.1). This measurement is usually done by divers with all the run risks of such situations ! (and the poorness of the information !).

For this measurement, the required accuracy was $\pm$ 5 mm and the reached accuracy was $\pm$ 3 mm.

5. THERMAL CHAMBER

The reasons for the measurements mentioned above (nuclear and underwater environment) are mainly maintenance purposes or incidents. Before these problems happen, digital photogrammetry could be very helpful to make some tests regarding deformations. Typically, ESIC carried out measurements of deformations under different temperatures of composite components for cars (0/+50°C).
Another typical application carried out by ESIC is the measurement of antennas (-40°C/+60°C) - (see figure 3.1). For this kind of measurement, the final result is the numerical comparison between the different temperatures and moreover, some graphical display made of isolines or colours (see figure 3.2).

6. THE FUTURE

All the measurements described above are different and similar. Different because medium is not always the same and the required accuracy is variable. Similar because there are all issued from the same problematic :
isolated sensor measuring through a glass and through different media.
We can easily imagine now, due to the efficiency of the digital photogrammetry, a new world for 3D accurate measurements : a world hazardous for man but neutral (or quite) for CCD sensor (!).
This new possibility also opens the way to an interesting approach : we are able today to catch a 3D information but also a thermal or a gammametric information : we should be able soon to synthesise all those information in a unique and useful 3D model !

We have also a dream for the future (and with the small eye of our knowledge) that some interesting measuring research aspects concerning the multicamera system should allow the real-time, and some robotics research aspects should drive us to the fast 3D modelling and the data transfer without cables !

Please find all figures on a colour page at the end of the volume