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GAMMA-3D CARTOGRAPHY: 3D LOCATION OF HOT SPOTS BY PHOTOGRAMMETRY

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ABSTRACT

Over the past fifteen years ***Photogrammetry***[1] *(i.e. dimensional measurement from images)*, has been improved and increasingly used for applications in nuclear environments, such as real-time assistance for modifications as well as 3d As-built CAD modeling for simulation or dismantling preparation.

In the meantime, Gamma cameras have been developed. These developments have generated 2d images of nuclear areas with gamma hot spot superimposition, which gives an approximate location of the hot spots. The accuracy of this location, however, depends on the equipment density and on the different points of view accessible to the camera.

By combining the two techniques of Photogrammetry and Gamma Image Processing, it appears that the position of hot spots can be measured with a higher accuracy and without any ambiguity. Additionally, the 3d (local) CAD modeling of the equipment may help in the estimation of dosimetry. This is made possible by providing the distance from the camera locations to the hot spots and the geometry of all the equipment crossed by the gamma radiation.

This paper will describe the principles of such measurements and will outline the benefits and the constraints. Some real examples will be presented and future developments will be discussed.

1 INTRODUCTION

Any modification or maintenance operation on an industrial installation and even more so in hazardous environments requires an increased amount preparation. Usual means, such as drawings consultation or human experience are interesting but have strong limitations. For example, drawings may not be up-to date due to missing information or geometrical/dimensional evolution with time. Also, with the increasing turn over rate due to retirement, there are very few seasoned and experienced professionals maintaining the upkeep and modifications.

Therefore 3d models appear as a very powerful solution, allowing simulation and optimization before actual live and applied operation. For current installations it is still possible to use conception models since more and more installations are designed with a 3d CAD software. However, for old installations such a model has to be created. Depending on the specific situation, it could be created from existing drawings but will still contain the same reliability risks as the simple use of drawing. Alternately, it could be created from Photogrammetry surveys, which will become a so called “As-Built” or “As-Existing” 3D CAD model.

Although it is essential to have updated 3d information prior to entering in a nuclear area, it is even more critical to have radiation and contamination information. The development of Gamma Cameras addresses part of this issue. Much like the imaging technique pairings of Gamma measurement and Photogrammetry, combining both 3d and gamma information is a logical choice to provide a unique and powerful simulation and preparation tool.

2 PHOTOGRAMMETRY APPLICATIONS

The main applications of Photogrammetry in industry are concerning the measurement of large volume objects such as aircrafts, telescopes, off-shore platforms and nuclear plants. The use of photogrammetry is very often driven by the size of the objects to be measured, since no other technical solution is available. Additionally it can be driven by hazardous environmental conditions (that forbid usual methods and means) such as radiation, high temperature, vacuum, and underwater.

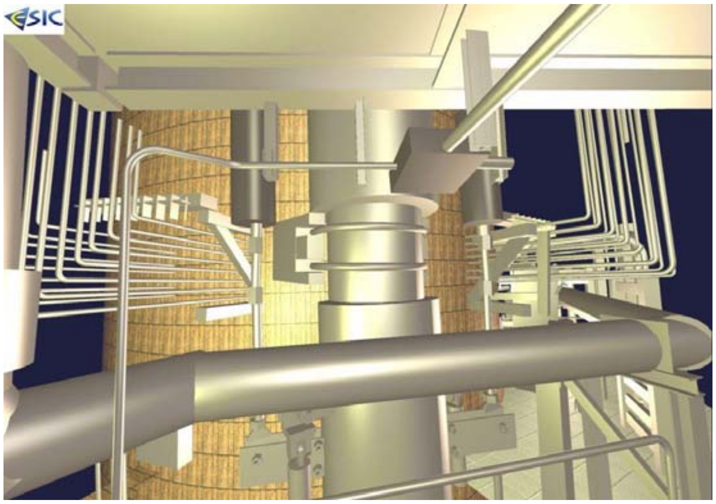
In nuclear areas, photogrammetry allows for remote controlled measurements by using remote controlled digital cameras or even very basic on-site vision cameras, depending on the final requirement in terms of accuracy. In some cases, a canister can protect the camera. By using a 45 degrees mirror, damage to the image, due to a high level of radiation, can be avoided. The success of this technology is due to many factors, including the low cost of the camera, which could pose as potential waste, and its easy introduction into any environment.

Following is a description of the main applications, namely As-Built CAD Modeling and High Accuracy Measurement.

2.1 As-Built Modeling

In this case, the goal is to create a 3d As-Built CAD model of the nuclear installation. This will provide real dimensions, since current drawings might not be up-to date. It will also prepare modifications. This is done so specifying, for example, the geometry of new components to be assembled, or plan dismantling, by getting an accurate inventory of fixtures. Additionally it will simulate further operations, such as studying the path out for components to be removed or optimizing the path of future operators. The required accuracy is generally between +/- 2mm to +/- 10mm *(0.08 inches to 0.40 inches)* (Figure 1).

Figure 1: 3d As-Built CAD model of a Nuclear Power Plant



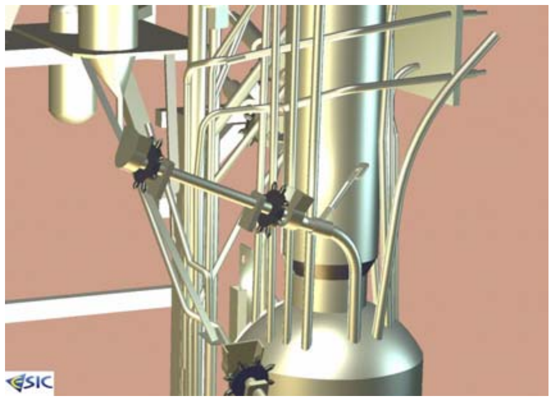
Such surveys are carried out with remote-controlled cameras or operators handling cameras, depending on environmental conditions and time constraints. New developments in the field of Photogrammetry allow for avoiding any targeting, which is usually required for Photogrammetry. This considerably reduces the duration of the survey. Further developments will eventually lead to a high level of data processing automatism.

This As-Built 3d CAD model is also very useful for communication purposes, such as training sessions for operators or detailed explanation for safety authorities. Since many 3d Viewers software and freeware are readily available, it becomes very easy to share such a CAD model and explain with a high level of realism any technical operation to future operators or any safety consideration to authorities.

2.2 High Accuracy Measurement

In this case, the goal is to provide very accurate 3d information, such as XYZ coordinates, for new components to be assembled. The required accuracy is generally between +/- 0.1 and +/-0.5 mm (0.004 inches to 0.02 inches). It concerns mainly interchangeable equipments, which are periodically replaced by new ones and have very accurate interfaces with other components (Figure 2).

Figure 2: typical equipment to be replaced in a Nuclear Fuel Reprocessing Plant

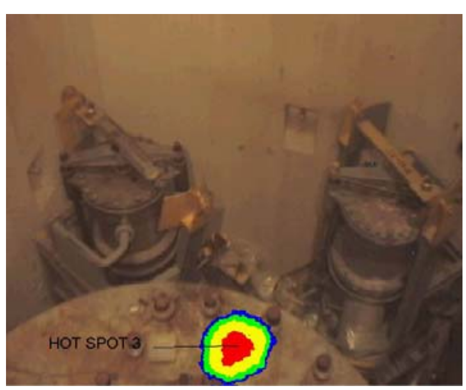


Considering the required accuracy, some measurement tools, such as mechanical targets, are generally necessary to identify precise interfaces like as holes, planes or flanges.

3 GAMMA MEASUREMENT

For the applications described above, nuclear radiation measurement is oftentimes carried out, for environment analysis and safety purposes for human operations. Portable Gamma Cameras, such as CARTOGAM[2], have recently been developed to detect hot spots and try to find their approximate location. These cameras provide both a gamma image and a superimposed visible image, allowing to identify hot spots and to find their approximate location (Figure 3).

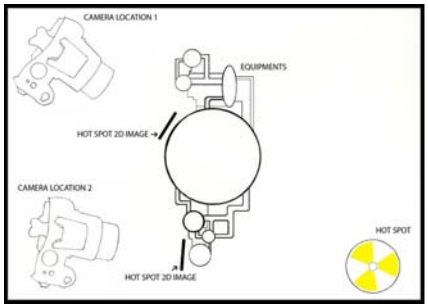
Figure 3: gamma and visible superimposed Images



Interpretation of such images quickly becomes a key factor, especially in very dense environments.

Location of the hot spot can be extrapolated from the superimposition of components on the gamma spot. However, depending on the environment, it could be manifestly inadequate. For example, if a nuclear cell has large and dense equipment behind which there are other equipments impossible to see and to reach, the hotspot will be seen on the 2d Image as being on the front equipments even though it is actually located on the equipment behind (Figure 4).

Figure 4: Plane view of a typical configuration with 2d Images



Another critical piece of information is the **level of radiation.** This level depends among other things on the intensity of the source and position with respect to the source, such as the distance between the camera and the hot spot. Additionally, the level depends on the equipment that may be on the radiation path from the source to the camera. Once again some data can be extrapolated from the superimposition of gamma and visible images but without real confidence.

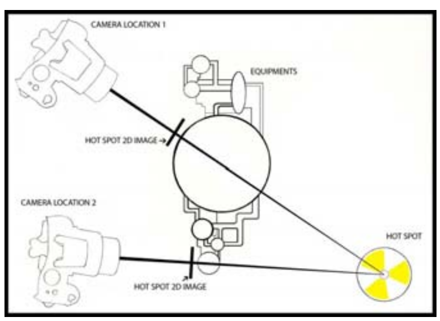
4 GAMMA-3D CARTOGRAPHY

These limitations, such as the approximate location and poor information about level of radiation, are the core stimulus for combining photogrammetry and gamma measurement.

4.1 Principle

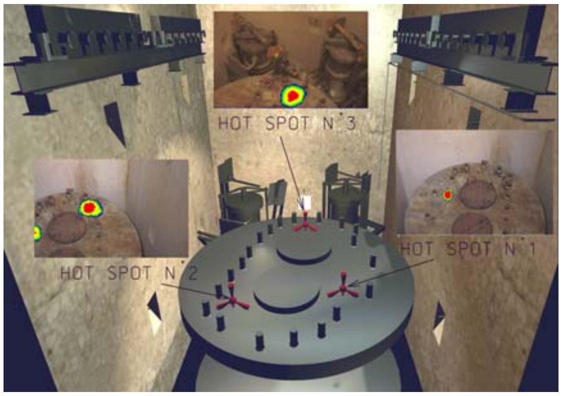
When the visible image is superimposed with the gamma image, it is possible to consider the gamma spot as an object and to triangulate its position as for any geometrical feature. This will produce its XYZ coordinates. In this case, although the hot spot is located in an invisible and inaccessible part of the cell, it can be triangulated and its position will be given with accuracy and no doubt (Figure 5).

Figure 5: Plane view of the same configuration as Figure 4 but with photogrammetry triangulation of the hot spot location



Moreover, as for any photogrammetric triangulation, the position of the camera with respect to the hot spot will be computed and the distance between the camera and the hot spot will be automatically given as an output. Last but not least, thanks to photogrammetry, the images can also be used to create a 3d As-Built CAD model of the hot spot environment. The 3d model will also have the capability of showing all of the equipment (or part of) on the radiation path from the hot spot to the camera. Such a 3d model will be very helpful in simulating operations, preparing protections and estimating the dosimetry that humans could integrate during further operations. In the **A**s **L**ow **A**s **R**easonably **A**chievable (ALARA) context, this becomes a very powerful tool (Figure 6).

Figure 6: 3d As-Built CAD Model with hot spot representation



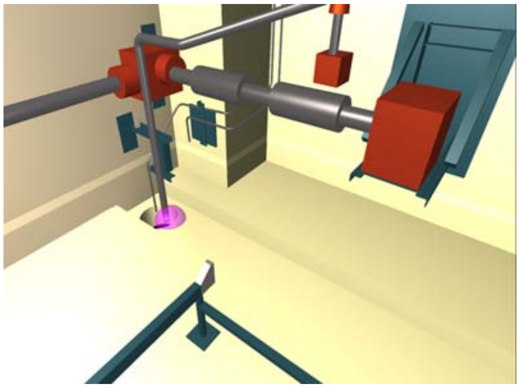
These developments have been carried out by the authors and are property of the AREVA Group (AREVA NC Patent[3]).

5 CASE STUDIES:

5.1.1 Nuclear Fuel Reprocessing Plant

In this example, the scope of work was to prepare further investigation to be done by operators. The remote-controlled gamma-3d survey provided a 3d As-built CAD model of the nuclear cell, including location of hot spots and their relative intensity. Operators were then able to study the setup of biological protections and optimized their task by avoiding the most radioactive parts (Figure 7).

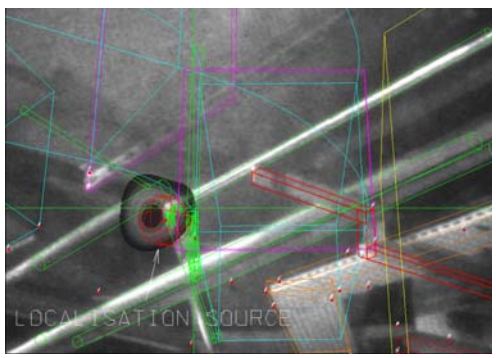
Figure 7: 3d As-Built CAD Model with hot spot representation



5.1.2 Nuclear Plant

In this example, the scope of work was to identify the exact location of hot spots prior to dismantling. In the dismantling process, equipments surrounding hot spots are usually the first to be dismantled by robotic means, thus decreasing the radiation level and allowing further operation by humans (Figure 8).

Figure 8: Visible Image and Gamma Image superimposed – 3d Modeling Process



6 LIMITATIONS AND FURTHER DEVELOPMENTS

Although this new measurement technique, called "Gamma-3d Cartography", has many applications and gives excellent results, there are some limitations due to the technology principles.

The main limitation is linked to the Photogrammetry Modus Operandi, which hinges on taking pictures from different points of view. For precise results, there should be at least 3 points of view and lines of sight should have intersections close to 90 degrees. However, in nuclear environments this is not always possible. Increasing the resolution of the cameras, for example, the number of pixels, could help in managing poor geometrical configurations but may not lead to substantial improvements.

Another limitation is related to the shape of the hot spot on the image. Triangulating a single, very focused hot spot gives good results, however, when a hot spot is spread out on one or more components, it becomes very difficult to identify a center and to triangulate a position. Further developments are being investigated to try modeling a basic 3d shape for the hot spot.

7 CONCLUSION

Both Photogrammetry and Gamma measurement have a lot of applications throughout the life-time of Nuclear Plants. By combining in some cases the two techniques, it becomes possible to provide with only a single shot, very accurate dimensional as well as gamma information.

The use of 3d As-Built CAD Models including gamma information becomes therefore an extremely powerful, cost and time-effective tool for the preparation, the simulation and finally the optimization of any operation from a single modification or any maintenance task to the final dismantling.

8 ACKNOWLEDGMENTS

✓ To the company ESIC for its major contribution.

✓ To the company AREVA for its authorization and support.

9 GLOSSARY

1. Photogrammetry: photo (light), gramma (drawing), metry (measurement). Photogrammetry is a dimensional measurement technique based upon the process of photographies. First experiences were carried out in the beginning of the 20th century, for mapping purposes, first applications in industry around 1980 (Shipbuilding, Nuclear Plants, Telescope Antennae) and main developments since 1995 with the arrival of digital technologies.

2. Gamma Camera: the CARTOGAM portable gamma camera, of particularly compact size (8 cm in diameter, 15 kg including the shielding), has been developed for gamma-imaging applications in nuclear facilities. The detector is composed of a CsI(Tl) scintillator, an image intensifier, and a charge-coupled device (CCD) matrix (CANBERRA).

3. AREVA NC patent: " Method and device for mapping radiation sources "
   N° publication in France: FR 2759791
   Date of publication: 1998.09.21