3D PLANT MODELS DERIVED BY ANALYTICAL PHOTOGRAMMETRY AND THEIR USE IN THE PREPARATION OF AREA CLASSIFICATION DRAWINGS

J.H. CHANDLER[1], R.M. LITTLEWORTH[2] AND W. VAN HAVERE[3]

1 Department of Civil Engineering
Loughborough University of Technology
Loughborough
Leicestershire LE11 3TU
United Kingdom

2 Engineering Photogrammetry Unit
City University
Northampton Square
London EC1V 0HB
United Kingdom

3 Monsanto Europe N.V.
Haven 627
Scheldelaan 460
B-2040 Antwerpen 4
Belgium

This paper describes how analytical photogrammetry was used to produce accurate 3D CAD models representing a large volume of chemical plant. Additional engineering information was added to these models and used to generate Area Classification drawings. This approach was found to be the most efficient means of producing such drawings, increasingly necessary to satisfy legislation on emissions and plant operating permits.

Traditional methods of producing Area Classification drawings are reviewed, followed by an overview of requirements of a photogrammetric survey. Application at the Monsanto plant in Antwerp is used to illustrate the methodology. The importance of photogrammetry to this type of application and to the petro-chemical industry in general is discussed.

Keywords: computer aided design, 3D models, area classification, photogrammetry, as-built data.

Introduction

The Area Classification Problem

Area Classification (AC) reports and associated drawings are mandatory for the operation of process plant. Such classifications include the identification and qualification of hazardous areas in respect of potential emissions of gases, vapours, liquids and dusts, and the specification of selection criteria for electrical installation. Area Classification drawings which are produced must convey the spatial locations of all emission points to which all hazardous areas or zones are added. These documents are an important part of the operation permit dossier, and such permits are in the process of renewal during the 1990's for the Monsanto plant in Antwerp, Belgium. The Monsanto drawings must be based on up-to-date plot plans and ortho views and accurate as-built information representing the existing plant is necessary to generate such drawings. At Monsanto, such spatial information has formerly been produced by two methods:

- The archive of existing information was searched for suitable plots and plans of the plant, and such sources were used to provide the basis of a new series of up-to-date drawings. In practice this approach proved to be costly because the engineer was occupied for considerable periods of time searching and updating material that was available. The modern alternative of scanning all relevant information from the archive was found to be equally intractable, mainly due to the sheer number of plans produced for the various projects executed during the lifetime of the plant.

- An alternative was to acquire up-to-date information using traditional field surveying. This approach had the advantage of providing accurate as-built information rather than original design data, which often differs from the finally constructed plant. However, this technique was found to be slow, time-consuming and expensive. Gaining sufficient access to plant represented a major problem, particularly in hot and chemically hazardous areas.

The Solution

Neither of these two approaches was found to be ideal, and a method which Monsanto in Antwerp identified as a potential alternative was to make use of the science of photogrammetry. A photogrammetric survey would be used to generate a 3D CAD model, with Monsanto personnel adding the necessary engineering information and producing drawings required for area classification.

Photogrammetry

Photogrammetry provides a series of techniques which allow the determination of accurate 3D co-ordinates, of known quality, using measurements derived from photographic images. Photogrammetric science was originally developed late in the last century[1] and has become established through application to small scale mapping using vertical aerial photographs[2]. Terrestrial photogrammetry has again become prominent since the introduction of the analytical plotter[3]. This plotting device is designed to automate the transformation of points measured from original photographic images into 3D co-ordinates. Recent developments in technology used for carrying out photogrammetric measurement have introduced a new branch to the science which has made an impact on the hardware used. Increasing speeds of computer processors, associated reduction in costs of memory and disc storage, and finally the development of high resolution CCD arrays has meant that digital photogrammetry is now feasible. This involves the use of a digital plotter employing a scanned or digital image as the source for image measurement and subsequent transformation into 3D co-ordinates. The functional basis of analytical and digital terrestrial photogrammetry is very similar, differing only in system implementation. Both techniques can be considered as providing an effective method of carrying out a measured detail survey, which is often more appropriate than direct methods of field surveying. In the future, digital photogrammetry will become more dominant as technology improves further and advances in automated modelling methods become more robust[4].

Photogrammetric methods have been employed and reported in the petro-chemical literature. Bracewell and Klement[5] used photogrammetry to record the location of pipes and piping racks, and such an application has been similarly applied more recently by Spear[6]. Zicarelli[7] reports on photogrammetry used to derive an accurate 3D as-built CAD model of a vessel and surrounding detail occupying a volume 9m x 16m x 10m of plant. Photogrammetry provides a non-contact system of measurement which is particularly suitable for measurement within hazardous environments[8] such as the Nuclear Industry[9]. Photogrammetric methods can also assist during the critical phase of a plant upgrade, by ensuring that components fit together during re-assembly[10]. Despite these applications, usage of photogrammetry within the industry is not widespread.

It is the aim of this paper to outline the processes involved in tackling the Area Classification problem using photogrammetric methods. The advantages of using this technique will be discussed in the context of practical experience gained whilst applying the method at the Monsanto plant in Antwerp. It is the authors' view that photogrammetry represents a cost effective alternative to solving the Area Classification problem.

Area Classification using photogrammetry

There are several well identified stages for carrying out Area Classification using photogrammetry.

Photogrammetric survey

The first stage is to visit the site and acquire suitable photographic imagery of the required plant area and to carry out a control survey.

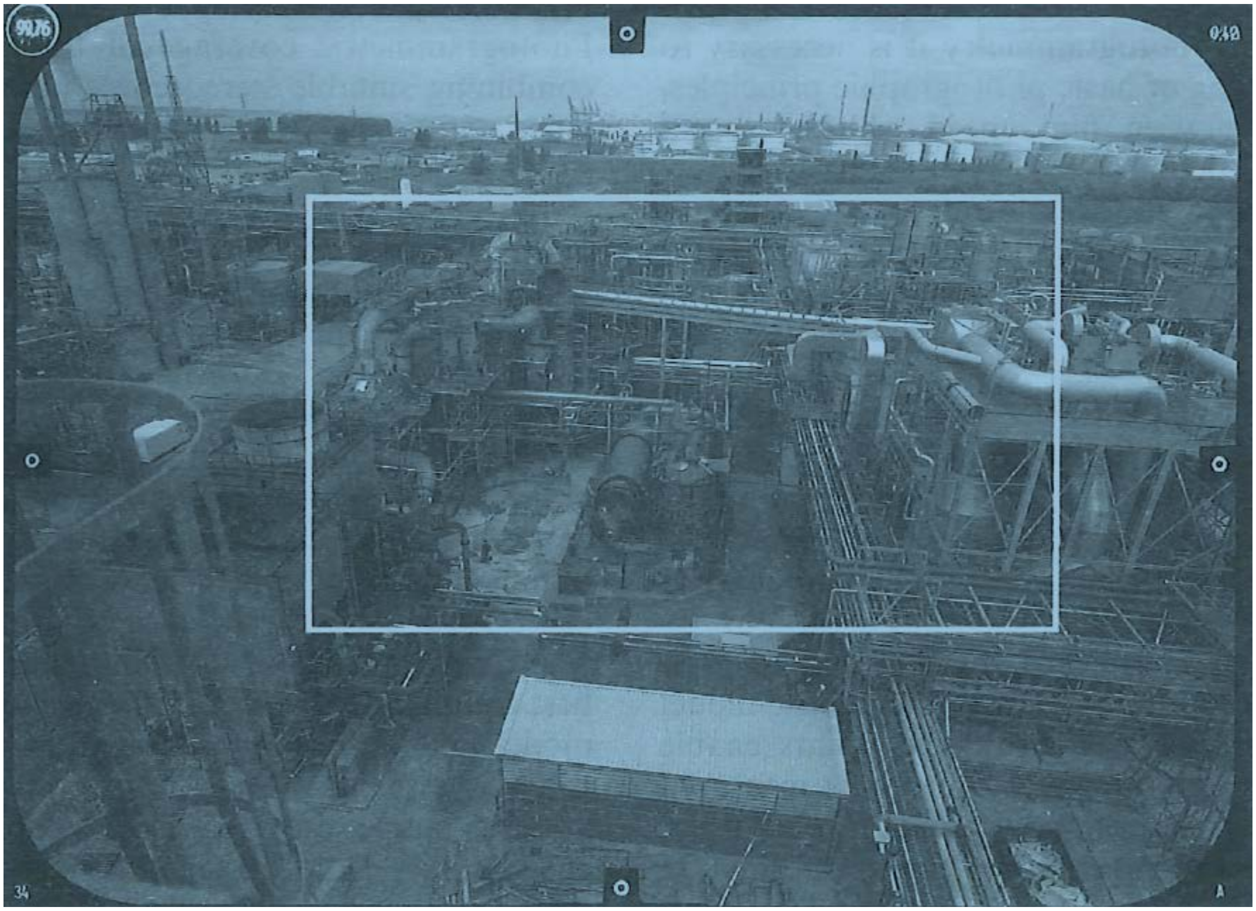

Plate 1 UMK photograph of Monsanto plant

Photo acquisition

A photogrammetric or metric camera is best used for obtaining imagery suitable for measurement. Such a camera is designed to fulfil certain geometric characteristics essential for simplifying the photogrammetric process. Aerial photographs and ground based photographs can be used, whilst the viewpoint provided by a hoist or from the roof of an adjacent building is particularly valuable for tall structures (Plate 1). A minimum of two photographs taken from slightly differing locations is required; this provides the stereoscopic overlap (Figure 1) which is essential for deriving three-dimensional information. For optimum precision in the object space a basic geometric relationship between the two camera positions and the object distance must be maintained. This simple relationship is known as the base/object distance ratio and should be between 1:3 and l:10 for normal photogrammetric measurement and analysis (Figure 1). Conventional photogrammetry is based upon photographic emulsions as the medium for recording information and subsequent measurement. To obtain images which are of sufficient quality for photogrammetry it is necessary to have an understanding of basic photographic principles. The relationship between

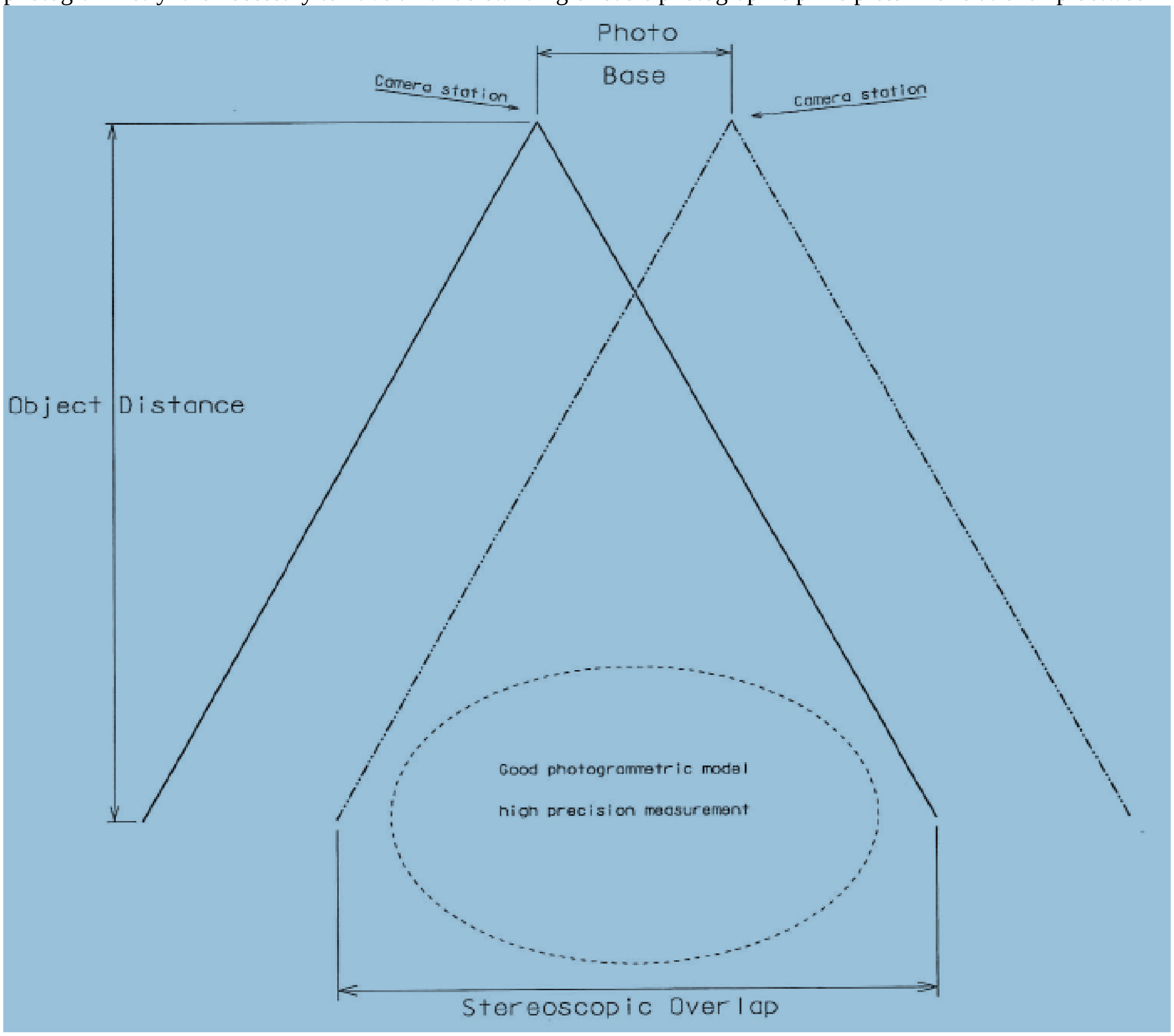

Figure 1 Sterescopic overlap and base/object distance ratio.

film speed, shutter speed, aperture, focus and depth of field is particularly important. Developments in the technology of CCD arrays suggest that capture of digital imagery directly in the field will become more important in the future.

Control survey

The purpose of the control survey is to ensure that any three-dimensional co-ordinate acquired from one pair of photographs or photogrammetric model will be spatially related to other points derived from all other models. This is achieved by ascertaining the 3D co-ordinates of prominent points appearing on the photographs by combining horizontal and vertical angles measured using a digital theodolite. During the photogrammetric model setting-up procedure these co-ordinated points enable the necessary transformation between points measured anywhere on the two images and their associated object co-ordinates to be determined. The control points are best identified using manufactured targets and commonly consist of a black and white cross which can be attached to a structure for the duration of a survey. It is often impossible or dangerous to gain access to the top of a steel structures. A safer alternative is to select well defined points, such as corners of steelwork, as a natural form of target. A theoretical minimum of three such targeted points must appear on any pair of photographs used to set up a model, although five points provide the redundancy necessary to ensure an accurate solution. Photogrammetric coverage of the site is obtained by combining suitable stereoscopic photographs each provided with an adequate number of control points.

Photogrammetric analysis and modelling

The process of measurement and modelling consists of several distinct phases.

Control computation

The three-dimensional co-ordinates of the control points must be computed using the desired datum as a co-ordinate reference system. Ideally, all measurements obtained during the field survey should be combined in one least-squares variation of co-ordinates estimation[11]. The incorporation of all redundant data provides the best estimates for the co-ordinates and a full stochastic model enables the precision of all estimated co-ordinates to be assessed. Arbitrary local grids should be avoided and the single site grid used whenever possible. This ensures that detail obtained from one area of a site is spatially related to detail acquired from another, and provides a datum for any future survey.

Photo processing

The photographic negatives must be processed and contact prints made; such prints are not essential but are valuable for assessing coverage and marking the position of control points. If a digital plotter is to be used for measurement then images must be scanned at an appropriate resolution using a high resolution and geometrically stable scanner. If an analytical plotter is available then the original negatives can be used for measurement.

Setting up models for measurement

Both the digital and analytical plotter require certain procedures to be carried out before reliable 3D co-ordinates can be acquired from any selected pair of photographs. The three-dimensional co-ordinates of the control points and other critical parameters associated with the camera, model and photo numbers need to be downloaded into the database of the instrument. Once complete, the selected pair of photographic images are either loaded from computer disc in the case of the digital plotter or mounted physically on the stage plates of the analytical plotter.

A two (or sometimes three) stage orientation process is carried out to set up the model suitable for stereo-viewing and detail measurement. This process involves measuring the image positions of critical points imaged on the photographs and determining various transformation parameters. Points measured include fiducial or reference points, which are produced by the photogrammetric camera (inner orientation). Also measured are the image locations of the control points established during the control survey (simultaneous orientation). In a simultaneous orientation or bundle adjustment[12, 2] both the measured image co-ordinates and the known object space co-ordinates of the control points are used in a least-squares estimation to determine the position and orientation of the two cameras at the instant of photography. This process establishes the relationship between any new point measured on the pair of photographs and an associated three-dimensional object space co-ordinate. Once derived successfully, these orientation parameters are stored and the data acquisition phase can begin. This orientation procedure must be repeated for all required models.

Data acquisition

Data acquisition involves the measurement of critical points of required detail and the building up of a framework of points and lines necessary for the creation of a 3D CAD representation. The procedure is a manual process in which the photogrammetrist viewing the model stereoscopically identifies a critical point of detail, manually adjusts a hand held controller until a floating mark is set on that point and the 3D co-ordinates are recorded. Both the digital and analytical plotter can be interfaced with a 3D CAD system which stores all measured co-ordinates. Basic CAD elements such as lines and simple shapes can be recorded; these features are used more frequently than simple point elements. Some instruments are equipped with superimposition which portrays all measured data correctly superimposed over one or both of the photographic images, so avoiding duplicated measurement.

Editing/modelling on graphics workstation

A 3D CAD system is based upon a system of mathematical shapes and forms (elements) spatially related in a 3D rectangular Cartesian co-ordinate system. In order to depict a 3D object in this framework, elements must be selected and used to construct a representation which is sufficiently accurate for the area classification task.

The editing stage involves building up a 3D representation of the plant using the photogrammetrically derived data. A variety of primitive elements can be used, but generally higher order elements such as shapes, circles, cylinders, B-spline surfaces and projected surfaces are employed. The photogrammetrically derived data provides a framework of points in the 3D space upon which these new elements are hung. The photogrammetrist selects the most suitable element to represent a particular component or feature and this is placed in the 3D space by snapping onto relevant measured data points or other points derived from them. The procedure involves a process of generalisation which does have implications for the accuracy of the final model. The modelling process can take a considerable period of time because it is a manual procedure and also needs to be done according to a pre-defined plan to ensure that detail is represented consistently throughout an area of plant. In the case of the Area Classification study reported here, the most important detail to be represented was the location of all vents and vent-lines. Detail and associated modelling elements used are shown in Table 1.

Table 1: Detail and modelling methods for Area Classification

Detail included	Elements and Modelling method
Structural steelwork	Projected boxes/lines
Vessels and tanks	Capped cylinders
Vents and vent-lines	Cylinders/projected circles
Pumps/compressors/plinths	Cylinders/projected circles/ boxes
Substantial pipes (> 0.4m diameter)	Cylinders/projected circles
Building outlines	Projected lines/boxes
Sewers and drain covers	Line-strings
Low retaining walls (surrounding vessels)	Projected lines
Roads and pavements	Line-strings

The modelling process is eased by knowledge that petro-chemical plant is generally set out according to a rectangular cartesian system. Data can be stored on different layers or levels and with varying symbology. This enables selective viewing of features and clear visual differentiation based upon colour, line-type and line thickness. An obvious way of structuring the data required for Area Classification is to place different feature types on different levels and with differing symbology. An important property of most higher order geometric elements is the surface characteristic. The use of elements with this attribute allows the 3D model to be used in further computational procedures. The most striking is rendering in which the CAD model is used to generate a pictorial representation from any viewpoint in space. A related operation is hidden-line removal which can also produce a photo-realistic representation of the object (Figure 2). Clash detection software can also be used to identify elements which occupy the same volume in space and can be valuable if the CAD model is to be used as a basis for the design of new additions to the plant.

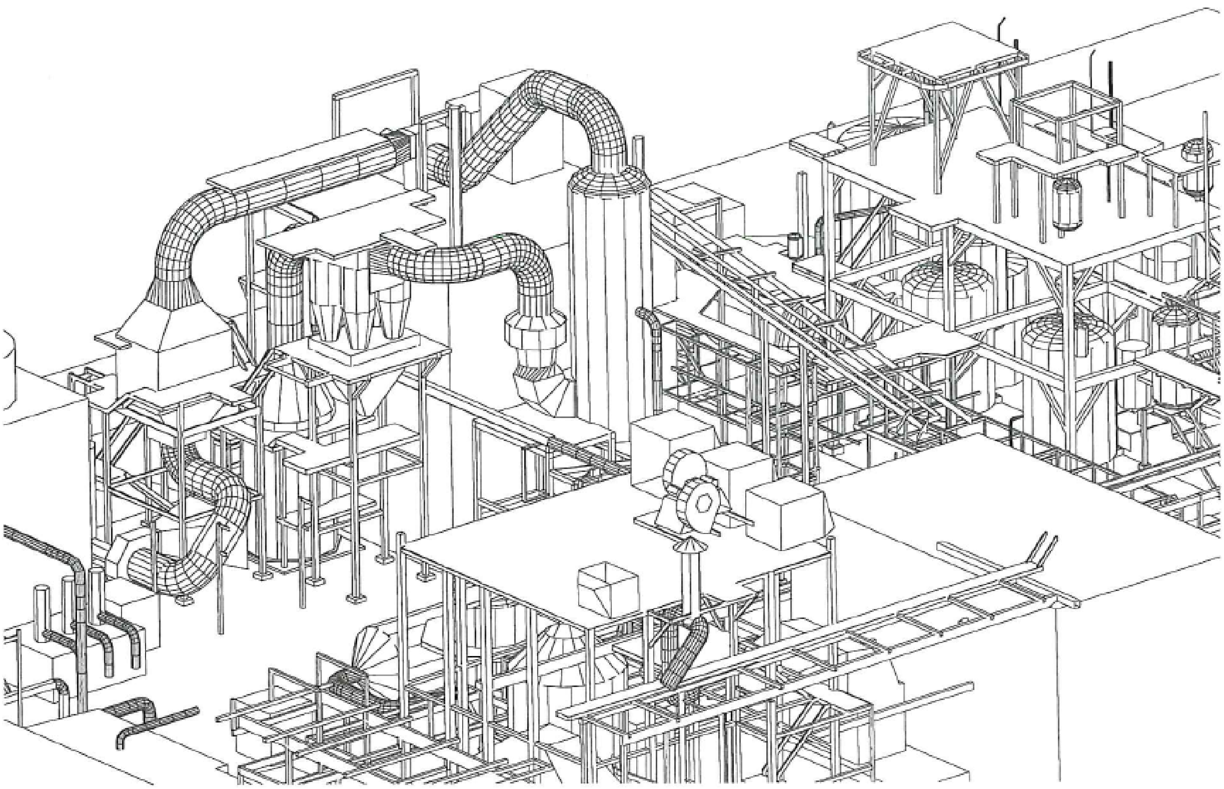

Figure 2 3D CAD model of an area of plant, with hidden line removal (area indicated on Plate 1).

Field checking and quality control

It is virtually impossible to gain full photogrammetric coverage for a whole site during one photogrammetric survey, particularly where the modelling involves complex sites such as areas of chemical plant. In the worst case additional photographs and control survey data may be required, although usually it is a question of obtaining one or two taped distances to ensure consistent and accurate modelling. A second site visit is invaluable for quality control; a simple visual check ensures that all required data has been represented and small items not missed. Additional check distances between points of detail can confirm that required accuracies have been achieved. Following field checking the chemical engineer can be supplied with the required data files, complete with a record of levels and symbologies used.

Addition of engineering data and production of Area Classification drawings

The supplied 3D CAD model is used to generate a set of layouts and ortho views of individual units of the plant. Detail can be selectively displayed and plotted according to requirements, and the hidden line process generates the final as-built information. Hazardous areas and process data are added to the drawing, the classification including:

- type of flammables/dust
- indoor or outdoor locations
- type of ventilation
- leak sources and their location
- type of process equipment or operation

Notes are included on Area Classification drawings that document the basis for the indicated classification and provide a source of relevant data. In particular, the notes indicate:

- zone type
- names and characteristics of the flammables involved
- references to classification figures/sources
- temperature class
- dust class

The final Area Classification drawings (Figure 3) and document are then sent out to the authorities for approval.

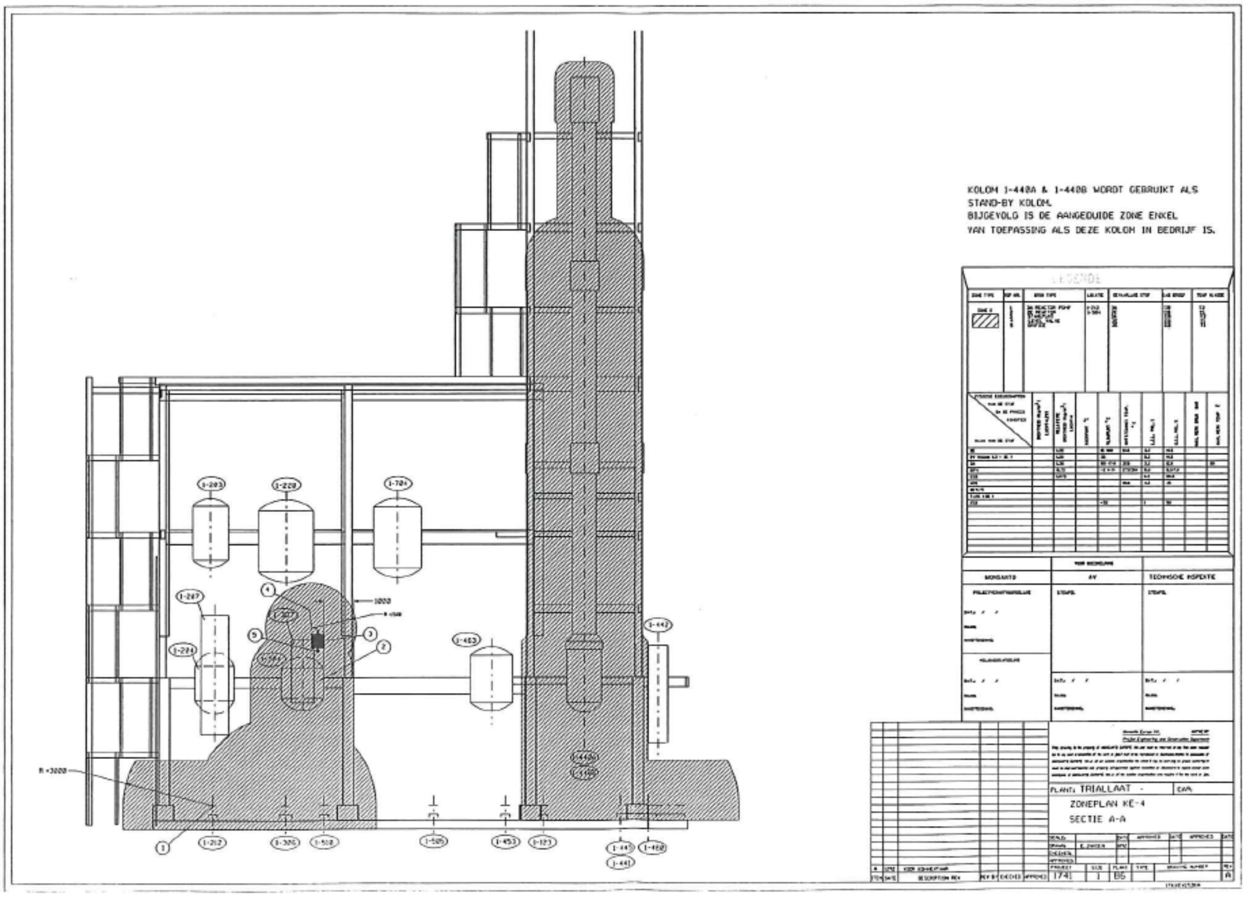

Figure 3 Final Area Classification drawing.

Practical application

Initial experiences

In November 1991 the Engineering Photogrammetry Unit (EPU) at City University were contracted by Monsanto to carry out a photogrammetric survey of the Triallate Plant and to produce a CAD model, to an accuracy of ±30mm, suitable for Area Classification. This plant occupied an area of one hectare of the plant in Antwerp and consisted of four areas of plant separated by narrow access roads. Some of the plant was complex and enclosed; and consisted of steel structures to a height of 30m (Plate 1).

Fieldwork consisted of obtaining forty pairs of photographs taken from the ground, a hoist and an adjacent walkway using a large format and metric UMK camera. Additional smaller format photographs were also acquired using a P32 metric camera to fill in some areas and provide backup coverage. A control survey established the co-ordinates of sixty control points, of which 25 were natural features such as corners of steelwork. Additional field survey work was carried out to position outlying drains, roadways and pavements which would not appear on the oblique photographs of the plant. All fieldwork was carried out in 3½ days.

The process of computing control, setting-up models, measurement and modelling was carried out in the UK. No major problems were encountered although several issues became apparent. The sheer size and complexity of the plant and required measurement/modelling was initially daunting. This was resolved by dividing the plant into more manageable areas and ensuring that all measurement and modelling was carried out before measuring new areas. A more serious problem was encountered with the viewing perspective and hence digitising capability afforded by the photographs acquired on site. The oblique and terrestrial viewpoints were found to be ideally suited to measuring detail on the sides and within structures but totally ineffective for measuring detail on top of structures and on the ground. Another problem area was experienced within one large building. With all the complex piping and vessels it was impossible to obtain the positions of the required detail from vantage points outside of the plant. To acquire the data necessary to position these details by photogrammetry would have required a larger number of photographs and a more substantial control survey to have been carried out. These limited areas of missing detail were left for Monsanto personnel to derive by simple taping on site.

An efficient approach

The completed model of the Triallate site proved that photogrammetry provides an efficient method of generating a 3D as-built CAD model of chemical plant. It was judged that improvements to the methodology were possible, particularly with the requirement for modelling four further areas, covering a total of 5 hectares of complex plant.

It was recognised that a combination of three survey methods would be most cost-effective, namely traditional field survey in association with both terrestrial and aerial photogrammetry. Photogrammetric techniques are particularly cost-effective when large amounts of detail appear on a limited number of photographic pairs. It was decided that it would be cheaper to position internal building data directly using traditional ground survey methods, and to use photogrammetric methods only for exterior areas of plant. All external detail could best be obtained using a combination of terrestrial photographs and aerial photography. A particular development in aerial camera technology known as Forward Motion Compensation (FMC) would enable the required accuracy tolerances of ±30mm to be met. FMC is designed to reduce the effect of image blurring due to motion of the aircraft whilst the shutter is open.

Aerial coverage

A specification for the aerial photography was established and various aerial survey companies were requested to supply quotations. The specification included coverage of the whole Monsanto site (1500m x 800m) at a scale of 1:2,500 with 80% end lap, 50% sidelap and FMC. The end lap refers to the percentage overlap between successive exposures along a strip of aerial photographs, with a minimum of 50% necessary for stereoscopic coverage. Sidelap refers to the percentage overlap between strips of photography which provide systematic coverage of an area. Three strips of 47 exposures in total were required to obtain full coverage over the Monsanto site. This was felt prudent as the main cost associated with obtaining aerial photography is putting the plane in position during suitable weather conditions.

A network of pre-marked photo-control points was required to enable accurate 3D co-ordinates to be obtained from measurements of the aerial photographs. These points had to cover the entire block of photography and be clearly imaged on the negatives. Approximately thirty of these points were placed over the whole Monsanto site, each consisted of a white square (0.3m x 0.3m) either painted on tarmac or by a metal plate attached to steelwork or on grass. These points had to be sited away from overhead obstructions, needed to be inter-visible from the ground to enable a strong survey network to be measured and used to derive reliable and precise 3D co-ordinates for all photo-control points.

The aerial photography was obtained in mid-August l992 and the control survey for the pre-marked points was carried out in September, taking four days on site. The co-ordinates of these forty control points were established to a final precision of ±7mm. One important systematic error which had to be taken into account over such a large area was earth curvature and atmospheric refraction, the necessary correction being achieved by applying small corrections to all measured vertical angles. A further least-squares adjustment was carried out using the image co-ordinates of all pre-marked points measured on the aerial photographs. This final adjustment is known as a combined block adjustment, and was used to determine the exterior orientation parameters of all aerial photographs in the block. These parameters then enabled any pair of aerial photographs to be selected and used to provide accurate 3D co-ordinates for any point visible within the Monsanto site.

The first site that was worked on using the combined aerial and terrestrial photogrammetric method was the Sulphonamide plant. This occupied a total area of 1.5 hectares and included an area of enclosed plant inside a four-storey building. The aerial photographs were used initially to derive as much relevant detail as possible from the vertical perspective. This included all road, rail and roof detail and large proportions of other important features such as retaining walls and steelwork. This initial phase of data acquisition was found to be particularly valuable prior to carrying out the ground photogrammetric survey on site. It was possible to become familiar with the site layout and to identify potential problems before arriving on site. Working outline plots were produced and used to plan and identify likely camera and control stations.

Exterior using terrestrial photogrammetry

Site work for the ground based photogrammetric survey took 3½ days, with fifty pairs of UMK photographs being acquired and ninety 3D photo-control points established. A hoist was used to provide the view point for the bulk of the photography, but the roof of the main plant building provided a good vantage point for three important models. The site was more complex than the Triallate plant with large areas occupied by dense piping racks which tended to restrict many lines of sight. Processing, measurement and modelling using the ground based photography took six weeks, and integration with those data derived from the aerial photography took a further two days.

Interior ground survey methods

The survey work required to model the detail inside the plant building was subcontracted to a survey company. The survey techniques adopted combined traversing and co-ordinating of key detail points by bearing and distance measurements, and numerous taped distances were necessary also. The locations of key points were recorded on field sketches and Polaroid photographs, all essential to assist the modelling phase. A survey team consisting of two persons worked on site for three weeks, in conditions which were not conducive to accurate survey. Vibration was a key problem and occasional jets of steam and strong odours were also encountered. Modelling was carried out using AutoCAD and took a further four weeks. Some of the modelling was carried out locally using a portable PC, although it was found that the small screen was restrictive. Data from the supplied AutoCAD file were translated into the Intergraph CAD system.

The methodology outlined earlier was repeated for the Plasticizer plant and more recently the Lustraan and PPD plants. The solution has now developed and matured to the extent that reliable assessments of time required can be estimated and a high quality product produced (Figures 2 and 3).

Discussion

Principal benefits of photogrammetry

The authors consider that there is no other field survey technique which can generate an accurate as-built 3D CAD model of a chemical plant with the same efficiency as one based upon a photogrammetric survey. Other approaches are cumbersome and involve significant expense. Full and complex CAD models have never before been produced using ground survey methods at Monsanto, and so it has been difficult to quantify exact savings in both time and money. It is estimated that cost savings of approximately 60% and time savings of 40% have been realised during these projects.

The principal advantages of photogrammetry are :

• The photogrammetric solution is both cheaper and more rapid than conventional ground survey.

• Production is totally unaffected, required site access is minimised with the bulk of measurement and modelling carried out off-site.

• No special permits are required. The survey team do not require access to all plant/structures because photogrammetry is a non-contact survey method. Safety is not compromised and no special arrangements/permits are required.

• The photographs provide a permanent record of the plant which can be accessed at any time in the future, prior to a plant up-grade or perhaps following an incident. Such an archive of spatial information can be recorded cheaply as only the initial fieldwork costs are involved.

• Accuracies in photogrammetry are dependent upon the scale of the photographs. Hence, accuracy is flexible and can be varied depending upon requirements.

• Existing staffing resources are not unduly affected by this form of specialised out-sourcing. The only assistance required on site is an introduction to the installation manager, counter-signing of permits and organisation of a hoist.

• The added value of this technique is that an up-to-date as-built CAD model is produced of the plant. Such a model (Figure 2) includes major outlines of steel work and other structures, all equipment and piping. The model can be used to develop designs within existing units, as in the case of a plant revamp or for general improvements on the installations.

Limitations

Any survey method is restrained by certain limitations. In photogrammetry the required points must appear on a minimum of two photographs to be co-ordinated. In very dense areas of plant, particularly with complex piping racks, objects tend to obscure each other and make measurement of points difficult. This problem is normally counteracted by acquiring additional photographs, but in some areas it is virtually impossible to gain coverage whilst a plant is operating. This will be always be a handicap to this particular technique. Measurement is currently off-line. Photographs need to be processed and measured with results taking 24 hours at a minimum. Future research into digital photogrammetry may offer some assistance in this area because CCD array cameras are becoming cheaper and offer the potential of measurement in near real-time. Despite this potential the resolution of such imaging systems remains a critical problem; a typical CCD array camera may have a resolution of only 2048 x 2048 pixels compared to an equivalent resolution associated with the UMK camera of 32,000 x 22,800 pixels (assuming the silver crystals of the photographic emulsion are 5μm in size). Photographic emulsions will remain important to photogrammetry, although digital systems will become increasingly relevant as technology improves and becomes cheaper.

Data quality

Accuracy of data derived from photogrammetry depends upon two principal groups of factors, photogrammetric precision and modelling generalisation. Photogrammetric precision is defined by a series of interrelated influences including: type of photographs acquired; camera used; object distance and scale of the photographs; geometry defined between camera positions and the object; instrument used for photogrammetric restitution and quality of the original control survey.

Photogrammetric precision

Table 2 indicates the approximate photogrammetric precision of any data acquisition with the various combinations

Table 2: Photogrammetric precision as a function of camera and object distances

Type of Photography	**camera**	**focal length (mm)**	**format size**	**Object distance (m)**	**Photo. scale**	**Approx. precision (mm)** [1]
Terrestrial	UMK	100	160 x 114 mm	5-10	1:75	1.5
	P32	65	70 x 52.5 mm		1:115	2.0
	CCD array	25	2048 x 2048 pixels		1:300	7.0
Oblique	UMK	100	160 x 114 mm	20-25	1:220	4.0
	P32	65	70 x 52.5 mm		1:350	8.0
Verticals	Aerial + FMC[2]	150	230 x 230	375	1:2,500	30.0

[1] For well identified points and acceptable base/distance ratio
[2] Forward Motion Compensation

of type, camera, object distance and hence image scale. Achievement of this level of precision requires that a high quality control survey will be carried out, an analytical plotter will be used for measurement, and the base/distance ratio must be between 1:3 and 1:10.

Model generalisation

In order to represent a 3D object within a 3D CAD system, mathematical shapes and forms (elements) must be selected from a whole selection of possible alternatives. Different selections will produce slightly different models. More importantly the use of perfect geometric structures compromises the raw measured data in two ways. For example, points which are assumed to lie in a plane will be forced to lie in the selected plane even if the original co-ordinates do not. Second, a process of simplification, or more correctly cartographic generalisation, occurs during modelling when the operator decides to represent an object with any particular geometric element. A complete and perfect model can never be obtained; the only measure of success is if the model is of sufficient detail and accuracy to fulfil the requirements of the project. The concept of quality defined as 'fitness for purpose' is appropriate in this case; modelling of greater detail than necessary would lead to inefficiencies.

Currently, piping design software tools are being incorporated into photogrammetric systems, and these should make significant savings during the production of CAD models. It is important that strict control procedures are introduced otherwise there is a danger that consequent modelling may be carried out to an unacceptable level of generalisation.

Conclusion

The use of photogrammetry for Area Classification has been outlined, illustrated and discussed. The technique provides a flexible, non-contact and accurate method of generating a 3D CAD model of plant, ideally suited for Area Classification. Engineers do not need to spend time generating the CAD framework, rather their expertise and time is put into adding information necessary for production of Area-Classification drawings. An important by-product of the method is the as-built CAD model which is generated. This is valuable for future upgrade planning and general plant management.

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