

# 3D-DOCUMENTATION TECHNOLOGIES FOR USE IN INDUSTRIAL ARCHAEOLOGY APPLICATIONS

A. Gruenkemeier<sup>a</sup>

<sup>a</sup> Bochum University of Applied Sciences, Department of Surveying and Geomatics –  
antje.gruenkemeier@fh-bochum.de

**Commission WG V/2 – Cultural Heritage Documentation**

**KEY WORDS:** Application, Archaeology, Cultural heritage, Fusion, Photogrammetry, Terrestrial, Three-dimensional, TLS

## **ABSTRACT:**

Industrial archaeology deals with questions of industrial culture and preservation of industrial monuments. The concept was introduced in 1955 in England, after the Swiss engineer Conrad Matschoss had expanded the history of technology to industrial monuments in 1932. The objective purpose of industrial archaeology is the preservation and documentation of the industrial-cultural heritage of international importance – a task which is mostly to be fulfilled in a race against time and hence, needs efficient and fast technologies for data capturing. Prior to an (accidental) destruction of industrial-cultural objects a correct geometrical and/or visual documentation must be reached using new technologies from the field of data capture, management and use of space-related information.

This paper discusses interests in and problems of industrial archaeology, presents concepts for an integrated use of actual capturing techniques and shows typical applications.

## **KURZFASSUNG:**

Die wissenschaftliche Disziplin, die sich mit Fragen der Industriekultur und Industriedenkmalpflege beschäftigt, bezeichnet man international als Industrial Archaeology (Industriearchäologie). Der Begriff wurde 1955 in England geprägt, nachdem 1932 der Schweizer Ingenieur Conrad Matschoss Technikgeschichte auch auf die Industriedenkmäler ausgedehnt hatte. Objekte der Industriearchäologie sind alle jene ober- und unterirdischen Bauten, die seit Mitte des 19. Jahrhunderts erbaut worden sind. Die Dokumentation dieser international bedeutenden Zeit ist wichtig, aber häufig aufgrund der schnellen Abrissarbeiten nur schwer zu realisieren. Die einsetzbaren Messverfahren müssen sich diesen Umständen anpassen.

Der Aufsatz beschäftigt sich mit den Interessen und Problemen der Industriearchäologie, zeigt Konzepte zur aktuellen technischen Erfassung und gibt einige Beispiele.

## **1. INTRODUCTION**

Industrial archaeology deals with questions of industrial culture and preservation of industrial monuments. The concept was introduced in 1955 in England, after the Swiss engineer Conrad Matschoss had expanded the history of technology to industrial monuments in 1932. Objects of industrial archaeology are all aerial or underground buildings which were constructed since the mid-19th century at the time of the beginning of industrialisation. The end of the heavy industry in Germany (with its headgears, pits, gasometers and refuse dumps), which had decisively influenced the lives of people for a long time, disrupted many areas. Today the buildings can hardly be used. Because of the pollution of the grounds they must be disposed of. This is also true for the buildings.

The documentation of this internationally significant time is important, but in many cases very difficult to realise because of the often immediately following destruction of the objects (roll-over-method) and an alternative utilization of the terrain. With regard to economic reasons the progress of construction works must be very fast. A number of buildings dating from the industrial period are under threat of being demolished. The applicable measuring system must be adjusted to these circumstances.

Industrial archaeology is a special field of research: an interdisciplinary approach with multifarious basics which are

necessary for the investigation. It includes archaeology, construction history, architectural history, history of technology, ethnology, economic history, social history, history of art, cultural history as well as conservation of historical monuments.

Within the shared research project RIO (Spatial Information System For Survey, Documentation and Analysis Of Industrial Archaeology Objects) of the Universities of Applied Science Bochum and Mainz, together with the Departments of Archaeology, Essen and Dortmund, a documentation concept for industrial archaeology projects is developed (Supported by the Federal Ministry of Education and Research, 2007). Figure 1 gives an overview of the RIO-project [Boochs et al., 2006].

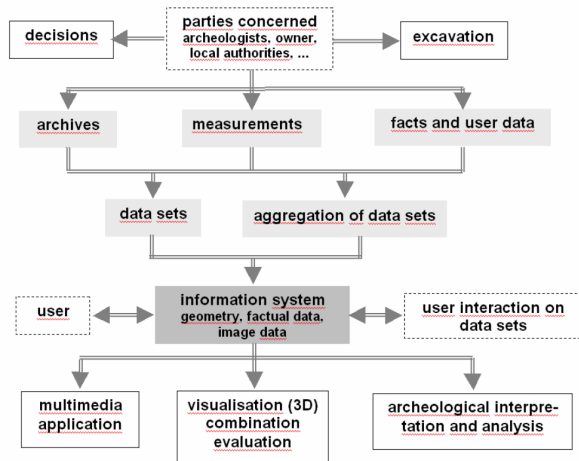


Figure 1. RIO project conception

## 2. DIFFERENT TECHNOLOGIES

Surveying is a basic component within the field of archaeological documentations.

The objective purpose of industrial archaeology is the preservation and documentation of the industrial-cultural heritage of international importance – a task, which is mostly to be fulfilled in a race against time and hence, needs efficient and fast technologies for data capturing. Prior to an (accidental) destruction of industrial-cultural objects a correct geometric and/or visual documentation must be reached using newest technologies from the field of data capture, management and use of space-related information. In most cases these have to be achieved under demanding conditions with respect to the

- size of the objects,
- shortness of the capture period,
- difficult accessibility,
- immediately following destruction of the objects, and
- huge costs which may originate when conventional documentation processes of archaeological findings are applied as well as follow-up costs when the construction site is left unexploited.

In this context the technology to be used must permit the shortest stay at the object and provide at the same time all necessary information required for the geometrical documentation and the technical and scientific analyses. These can be achieved only by modern 3-D measurement techniques which fix all necessary information in metric images and 3-D terrestrial laser-scans, add other geometrical and semantic information in a common geometrical framework and permit to process all existing technically information.

Some problems arise for industrial archaeology or for more conventional archaeological applications:

- An inventory of industrial objects taking into account possible underground findings has not yet been performed in Germany or, in some cases, has not yet even been initiated.
- The size of the objects complicates a usual capture and treatment within the scope of the archaeological fieldwork and seldomly the object is accessible in all phases of a building process without interruptions.

Measurements show an essential part of archaeological documentation. These contain the capture of single objects and/or building complexes as well as the topographic

environment, where these findings are located. Both elements should not be treated separately but form a unit.

### 2.1 Photogrammetry

The use of the image-based measurements in the framework of photogrammetry solutions has a long tradition in archaeology. The combination of stereo and convergent images, partly taken up from the “free hand”, simplifies the local recording methods and can be adapted to the object and the needs of the user. Flexibility, short capture times as well as the image documentation are important advantages of the use of photogrammetry.

In addition to close-range technologies a special value is introduced by aerial image measurement, here in particular for the capture of wide excavation sites. The photogrammetric evaluation process results in diverse products as, for example,

- digital rectifications (ortho-images),
- digital maps and plans (2-D),
- digital surface models,
- digital 3-D object models (e.g. video-representations), and
- a database of oriented metric images.

### 2.2 Terrestrial laser scanning

Terrestrial laser scanning is a relatively new measurement technology. The advantage of this measuring method is the contactless capture of objects in shortest time. The result is a 3-D point cloud (x, y and z) and a value of intensity (i) for every single point. The immense data volumes – up to several hundred millions 3-D-points with panoramic scans – make high demands on hardware and software systems. Necessary data reduction is very hard and lifelong because there is no or only dissatisfying automatic parameterisation for further processing in CAD- and geographic information systems. The process offers huge temporal advantages with the local capture of the objects compared to classical geodetic measuring methods. Nevertheless, the subsequent treatment of the measurement data within the scope of evaluation processes is complex and requires a detailed understanding of highly sophisticated technology and is mostly restricted to be used by surveyors. The active scanner generation makes possible 3-D capture of objects in close-up range (under 1 metre) or up to some hundred metres distance.

In combination with photogrammetric methods terrestrial laser scanning can introduce new techniques and products. The disadvantages of laser scanning are at the same time advantages of photogrammetry. Likewise, photogrammetry’s limitations are excellences of the laser scanning. So the combination unifies the advantages of both measurement methods.

An interesting application is the fusion of geometry information from the point clouds and the form information of the photo, the so-called “monoplotting”. With this method a 3-D object reconstruction with only one photo is possible: the additional information is extracted from the point cloud.

All products together build an excellent database for a spatial information system.

## 3. TYPICAL EXAMPLES

A typical example of situations in industrial archaeology is shown by the so-called west city of Essen in the Ruhr region in Germany: the area of the former Krupp cast steel manufactory.

In 2006 the management of ThyssenKrupp decided to build its new headquarter in Essen, the “ThyssenKrupp Quarters”. The excavation of an area of approximately 20 hectares took place before the constructions of the new headquarter could be started. From archaeological point of view the greatest difficulties at this building site are the:

- enormous size (figure 2 and 3),
- great progress of construction work: up to 6500 cubic metres soil were moved every day,
- time-frame for capturing was very short,
- weather conditions: the summer in Germany in 2007 was very wet,
- complicated accessibility.



Figure 2. Area of Krupp steel manufactory (1932)



Figure 3. Aerial photograph of “ThyssenKrupp Quarters”, above from 2<sup>nd</sup> May 2007, below from 23<sup>rd</sup> August 2007

In 60 days of work – between the two aerial photographs – the situation has changed completely: On average, 4000 cubic metres of soil were moved each day, all together about 240.000 cubic metres.

Because of the huge dimension of this building site a “normal” archaeological excavation is not possible (figure 4). In order to prepare the building site some geodetic measurements were

necessary. An existing net of points had been adjusted to the different terrestrial laser scanning systems and aerial image measurement; some tiepoints were tagged in the area. Because of the dimension of this area additional GPS measurements were sometimes necessary to get the position of the important relicts.



Figure 4. Some diggers in the building site

### 3.1 Forge

A forge is a typical example of an archaeologically interesting finding. It was used for melting metal and it was an important component in the steelwork.

Because of early investigations in the Krupp archive (one of the most important and biggest industrial archives in the world) it was expected that at that place a forge could be found. The whole area around the forge was categorised as archaeologically relevant so that a spontaneous measurement campaign was possible because of a good coordination in the run-up. When the forge was in fact found in the building site in Essen it was captured by laser scanning (Imager 5006 by Zoller + Fröhlich; Germany) and some photos. In six hours fourteen different scan positions were used to capture the forge and the topography around it as, for example, walls and fundaments. An area of about 20 by 30 metres was scanned. Additional GPS measurements were necessary for positioning the point cloud into the Gauss-Krueger coordinate system. After the local measurement the forge (diameter about 3 metres, figure 5) was demolished because a construction road was built there.



Figure 5. Forge and building site

In post-processing the point clouds of the different scan positions were linked together and afterwards they were registered. So the forge could be located in the superior coordinate system. To get a 3-D model of this forge all data (points and photos) were imported into the software *Geomagic* where a 3-D model can be created by a triangulated irregular network (TIN). One first result of this object is a realistic illustration of a forge (figure 6). The standard archaeological

work would include some views and horizontal cuts from the interesting object. For a conventional, archaeological capture (outlines by hand, views) there was not enough time at this building site. With the help of the scan data many standard products (e.g. plans in full scale) can be produced.



Figure 6. The forge: left as a smoothed 3-D model; right as a 3-D coloured model

This example of the forge shows that early archive work is necessary to be prepared for capturing. The progress of construction work is so fast that the time span (between finding an object and beginning to capture it) is limited to some hours only. The building site may not be disturbed by archaeologists and surveyors.

### 3.2 Bunker

In June 2007 a well-preserved bunker was found south of the Altendorfer Street in Essen. At that site there used to be a cast steel manufactory by Krupp, built in 1819. On the whole factory premises there used to be a close net of bunkers. Today there are only a few pieces of information about them and many of them are completely destroyed. In the Krupp archive this bunker is not listed so the found came as a surprise.

This bunker consisted of seven big shelters and their corridors. The rooms were closed by hard gas safety gates which are still intact. During street construction works four rooms were removed, three still exist. Every room has a size of around 60 to 70 square metres. Probably 450 workers could find protection in this bunker.



Figure 7. Screenshot of a scan

In the first room an inscription was found: “Für russische Arbeiter” (translation: For Russian workers) (figure 7). This is an important evidence that shelter was also provided for prisoners of war. This kind of information was brand new for the involved archaeologists since there had been no such hints in the Krupp archives [Hopp et al., 2007].

For the documentation laser scanning and photogrammetry were used. Around twenty scan positions were needed for the

documentation of the three rooms of this bunker. After the geometric documentation of the bunker it was closed to avoid further access.

### 3.3 “Turmhaus”

A completely different way of working is shown in the following example.

The former headquarter of Krupp in Essen was called “Turmhaus” (translation: tower house) because of its tower with a height of about 60 metres. For many decades the building accommodated one of the most important headquarters of the German industry with characteristic consequences for economic and political processes. The factory expanded and so a new building for administration was needed. All offices of the commercial department and accounting were accommodated in this building.

The “Turmhaus” had up to seven floors and the tower had a special meaning as a symbol of the importance of the building as the head office. In May 1976 the “Turmhaus” was completely demolished.

So for creating a 3-D model no local measurements were possible. The reconstruction was only realised by archive data, i.e. plans and photos. The complete 3-D model was created in Bentley MicroStation and is shown in figure 8.



Figure 8. “Turmhaus”: reconstructed from archive data

In the course of building measures in 2005 residual walls of the former Krupp headquarter in Essen were exposed. During a spontaneous measurement campaign an aerial survey and some laser scans were carried out with the Imager 5003 by Zoller + Fröhlich, Germany.

Figure 9 shows the actual condition in August 2005, combined with a plan from the Krupp archive.



Figure 9. Aerial photograph of cleared basement, combined with archive data

The projects differ in their procedure. The former headquarter of ThyssenKrupp, the so-called “Turmhaus”, was reconstructed from archive documentation without any local measurements. Another object, a forge, was documented by local terrestrial laser scanning with an Imager 5006 by Zoller + Fröhlich and additional photogrammetry measurements. For a global acquisition a series of aerial image measurement was carried out which realise an overview of the huge area.

The aerial photographs were taken by the so-called LEO-system (Local Earth Observation), a development of Bochum University of Applied Sciences [Baeumker et al., 1999]. This system is built for small-sized areas (some ten hectares). In this case the ground sample distance is up to four centimetres, so the aerial photograph is not only used for an overview but also as a source of information for archaeological finds. Because of the bad weather conditions a regular capture by air (twice a month, for example) was not possible.

#### 4. CONCLUSION

In principle, all of these capture methods can be made use of but it would have made sense to have an expert on location because of the great progress of construction work. A complete capture of the building site was not possible because the diggers destroyed archaeological relevant objects within minutes. The building site was not to be disturbed by archaeologists and surveyors. In order to finish the measurements interruptions of the construction work were not acceptable.

The roll-over method is very fast and economic for the builder. For the archaeologists this variant is unsatisfactory: only fragments of objects are exposed. In a conventional archaeological procedure a whole object can be captured and not only little sections. During a roll-over method at the building site this is not possible.

The example of the bunker shows that local documentation is necessary and worthwhile because the archives are often not complete.

#### REFERENCES

- Baeumker, M.; Brechtken, R.; Heimes, F.-J.; Richter, T., 1999. *Direkte Georeferenzierung mit dem Luftbildaufnahmesystem LEO*. Internationale Geodätische Woche, Obergurgl
- Boochs, F.; Przybilla, H.-J., 2006. *A Documentation concept for industrial archaeology*. The 7<sup>th</sup> International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST
- Hopp, D; Przybilla, H.-J., 2007. *Auch für russische Arbeiter*. Archäologie im Rheinland 2007
- Hopp, D; Przybilla, H.-J., 2007. *Krupp: a cast steel manufactory as archaeological resource*. Proceedings der Tagung “Big Stuff ‘07”: Beyond Conservation – Industrial Heritage Management. Bochum, September 2007
- Hopp, D; Przybilla, H.-J., (Editors), 2004. *Denkmäler 3 D*. VDV-Schriftenreihe 23, Wiesbaden

