

A HISTORICAL REVIEW ON PANORAMA PHOTOGRAMMETRY

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Commission V, WG V/1

KEY WORDS: Panorama, panoramic imagery, camera, history

ABSTRACT:

The paper presents a historical review of panorama image techniques with special emphasis on photogrammetric applications. The first part of the paper deals with the anatomic and visual properties of human vision where the use of panoramic views is evident for monitoring the environment, recognition, avoidance of collision etc. Naturally, the use of photographic panoramic images became very popular already in the 19th century. The paper presents some interesting panorama image acquisition and viewing facilities of the beginning of panorama photography.

Several photogrammetric applications are known in the field of close-range imaging and aerial imagery as well. They have always been used in very few and specific fields only. Analog panorama camera have been developed which have been used for photogrammetry and other professional applications. Different techniques are known for the acquisition of cylindrical and spherical images which are addressed by the report.

Today's increasing interest in panorama imagery is mainly initiated by simple digital cameras and simple stitching methods for generating panorama images. The fields of application vary from in-room monitoring, video conferencing, tourist purposes, weather forecast to mobile mapping and 3-D reconstruction. Today's high-level panorama scanners can produce images of highest resolution and superb quality. The combination with 3-D laser-scanners offers new potentials and applications.

1 INTRODUCTION

It is part of natural human behavior to observe the (three-dimensional) environment not only through stereoscopic viewing, but also through an all-around view over the partial or total horizon. The field of view of the single human eye is limited at 176°. By rotation of the head approximately 330° can be observed. Females have a slightly larger field of view than men. Only by rotating the whole body a complete 360° panorama can be achieved. Orientation and navigation in space becomes easier and more reliable if the complete surrounding can be involved into the perception process.

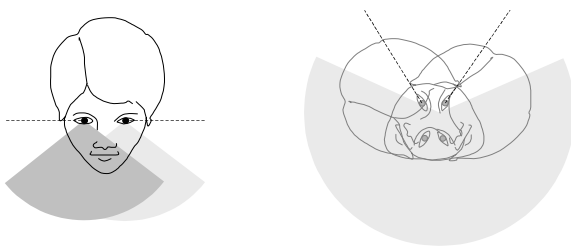


Fig. 1: Human field of view

Graphical panoramas are valuable tools to display the real 3-D world in a easy to understand manner. In cartography, panorama techniques are used for centuries in order to map three-dimensional objects (buildings, mountains etc.) into a two-dimensional drawing. Fig. 2 shows the example of a modern panorama map used for tourist purposes. The digital adaptation is shown in Fig. 3 where the same region is observed by a panoramic video camera where the images are presented in the internet in real-time. The example shows also, that the expression "panorama" is used for wide-angle views up to 360° panoramas.



Fig. 2: Cartographic panorama (Lenggries, Germany)



Fig. 3: Panorama camera and real-time image for Internet access (Lenggries, Germany)

Nowadays panoramic imagery has become very popular. Even low-cost digital amateur cameras are delivered with full- or semiautomatic stitching software that combines several overlapping images into a complete panoramic view. Therefore the availability and distribution of panoramic imagery has been increased, especially for internet applications. As one example, the official web site of the city of Oldenburg presents a slideshow of different panoramas of places of interest (Fig. 4).

In the following chapters the author tries to summarize the development of panoramic image acquisitions with special emphasis to their use in photogrammetry. Many of the mentioned systems are referenced to older photogrammetry textbooks. Some information and pictures are drawn from literature about the history of photography. A probably complete list of historical highlights in panoramic cameras is given by McBride (1994).

2 ANALOG PANORAMA IMAGERY

2.1 Early developments

As a consequence of the above mentioned human behavior it is not surprising that already in the early years of photography

several attempts were undertaken in order to enhance the optical field of view by appropriate camera solutions. When, around 1840, the technique of daguerreotypes became available for a wider group of people, mainly pictures of urban areas such as large squares, halls, monuments were photographed. Later in the 19th century, in the period of urban renovation and renewing, photography became more popular for the documentation of ancient buildings and cultural heritage. It is interesting, that both applications, urban documentation and cultural heritage, are again of major importance for the development of panorama photography in the late 20th century and recent years.

The first known invention of a panoramic camera dates back to 1843, when the Austrian Puchberger patented a swing lens camera. Fig. 5 shows a composition of eight daguerreotypes photographed by W. S. Porter in 1848. The set is one of the eldest panorama configurations known where a section of the horizon is imaged by a number of centered frame images. The principle is used up to date.



Fig. 4: Panorama image published under www.oldenburg.de

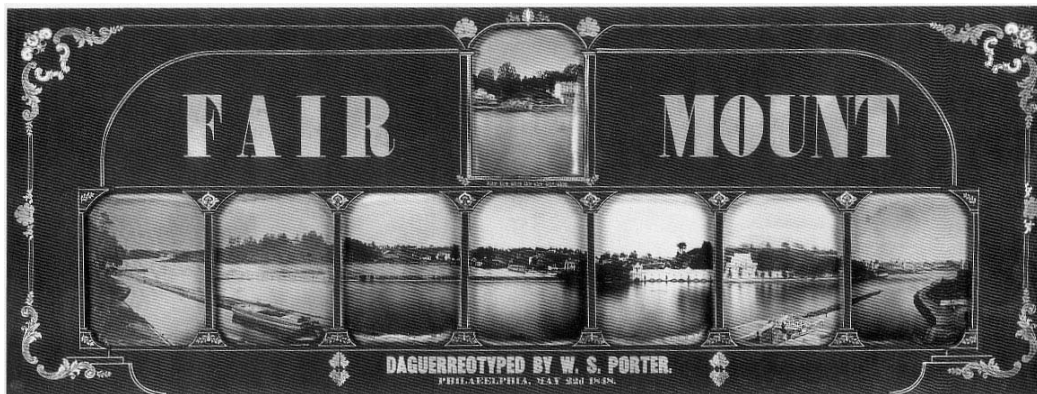


Fig. 5: Panorama composed by 8 daguerreotypes, 1848 (Frizot 1998)



Fig. 6: Panorama daguerreotypes, Paris, 1845 - 1850 (Frizot 1998)



Fig. 7: Technical brochure of the Al-Vista panorama camera (about 1899)

Fig. 6 displays one the first cylindrical daguerreotypes showing Pont-Neuf, Louvre and Quai de la Mégisserie in the city of Paris, acquired by an unknown photographer between 1845 and 1850. In this case the light-sensitive material was attached to a cylindrical image back. Fig. 7 shows an example of later professional panorama camera.

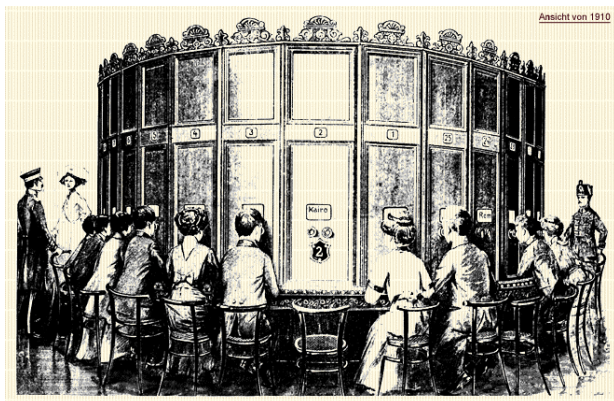


Fig. 8: Kaiser-Panorama (about 1910)

Panoramic arrangements of paintings and, later, stereophotographs were popular until the 1920s. The famous Kaiser Panorama (Fig. 8) is an example of an attraction for people who could watch a stereo slide show with changing motifs. Actually, the pictures were no panoramic images in our sense.

2.2 Modern analog panorama cameras

During the last 50 years several companies have specialized in manufacturing professional panorama cameras based on 35mm film and larger format, too. Basically, the following technical principles can be distinguished (Regensburger 1990):

2.2.1 Cameras with swing lens

Fig. 9 illustrates the principle of a camera where the lens swings around a vertical axis through the center of the lens. The film is placed on a cylindrical surface and it is exposed through a small slit. The field of view is restricted by the limited swing angle of the lens and the fixed film. Fig. 10 shows a swing lens camera with 120° angle of view.

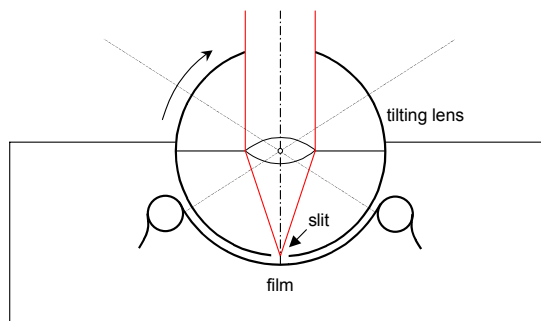


Fig. 9: Analog panorama camera with swing lens



Fig. 10: Zenit Horizon 202

2.2.2 Freely rotating cameras

Imaging angles of 360° or more can be achieved if a motor rotates the camera whereby the film is moving synchronously. As for tilting lens cameras the exposure time is a function of slit width and rotation speed. Fig. 11 shows a camera that is based on this principle.



Fig. 11: Seitz RoundShot 35

2.2.3 Cameras with spherical lens

Cameras equipped with a spherical fish-eye lens provide a panoramic view without any scanning process (example in Fig. 12). As an example, those cameras could be applied from a moving vehicle (Beers 1997).

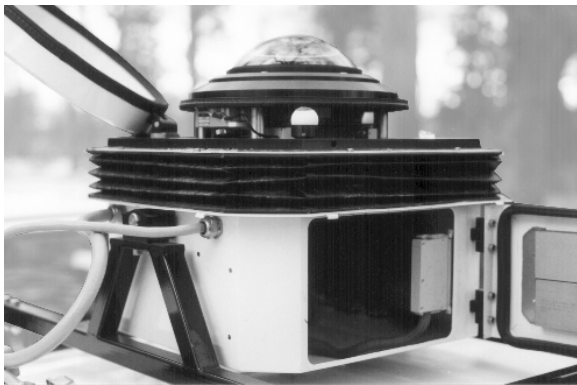


Fig. 12: Panorama camera with spherical lens (Frank Data)



Fig. 13: Spherical panorama image (Frank Data)

Fig. 13 shows an original spherical image. As a drawback of this technique, image resolution decreases with larger radius, and the image is harder to interpret. However, if the geometry of the lens is known from calibration, the image can be rectified, e.g. into a cylindrical projection (Fig. 14).



Fig. 14: Rectified image (Frank Data)

3 PHOTOGRAMMETRIC DEVELOPMENTS

3.1 Close-range panorama cameras

Already in 1858 the first photogrammetric panoramic cameras were constructed by PORRO and, independently by Chevallier. Porro's camera (Fig. 15) could be rotated around a vertical axis. The camera of Chevallier (Fig. 16) has consisted of a cylindrical shaped image area where an attached photo-sensitive paper was exposed (von Gruber 1930, p. 175). The panorama camera of Moëssard (cylindrograph, 1884, Fig. 17) shows a professional layout. Pelletan presented the first motorized panoramic camera in 1910.

However, early panoramic cameras were not used successfully in photogrammetry. Obviously, the main problem was the mechanical precision of the rotation mechanics, and the more complicated imaging model that required higher effort during the image restitution process. The problem of accuracy could be solved when theodolites and cameras were combined to phototheodolites by Porro (Italy, 1865) and Koppe (Germany, 1896). The followed devices by Finsterwalder, Zeiss (Fig. 18) or Wild were very successful in terrestrial photogrammetry since well-known geodetic methods could easily be adapted to photogrammetric purposes. The mapping of the Oasis of Dachel (Finsterwalder, 1874) or the Alps (Paganini, 1884) are famous applications of this technique.

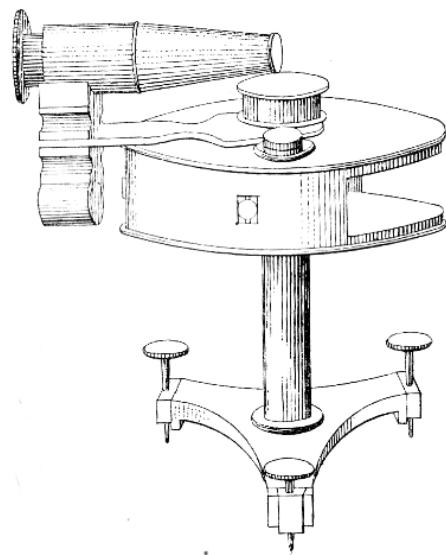


Fig. 15: Panorama camera by Porro (1858)

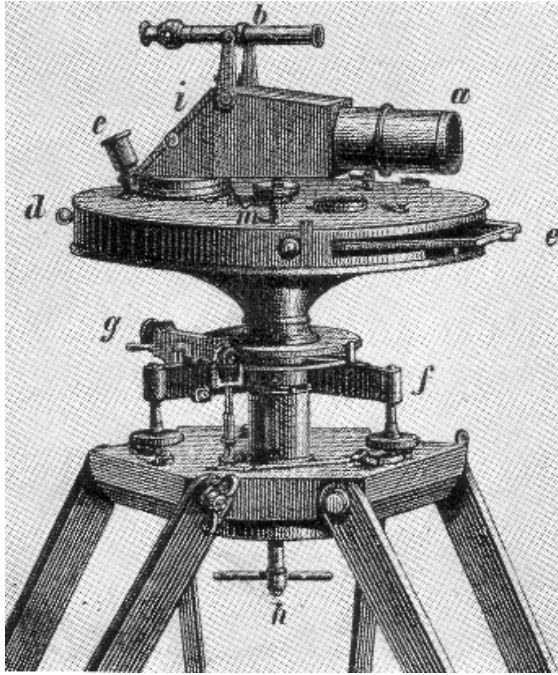


Fig. 16: Panorama camera by Chevallier (1858)

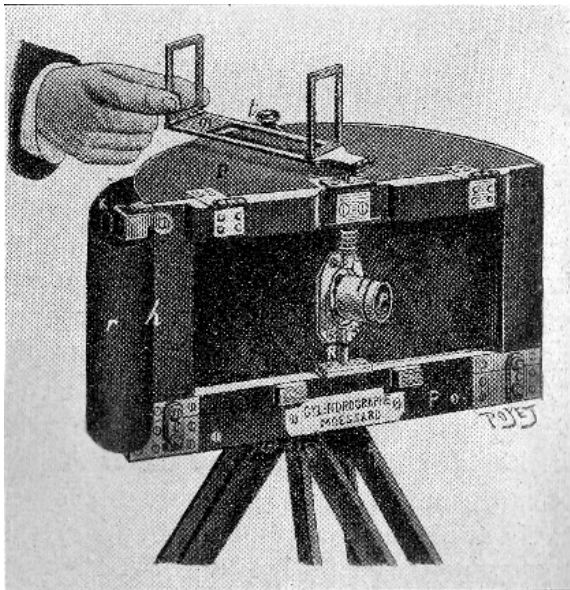


Fig. 17: Cylindrograph by Moëssard (1884)

The principle of combined image acquisition and angle measurement is still very useful in those applications, where a sufficient number of control and tie points can not be provided on site, or if multiple camera stations are not available. Video-theodolites and hybrid camera/tachymeter systems are appropriate solutions for high precision single-station monitoring or the measurement and documentation of complex interior structures (Chapman & Kotowski 2000).

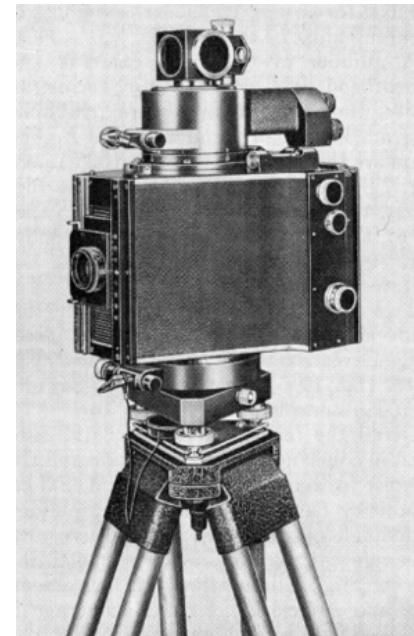
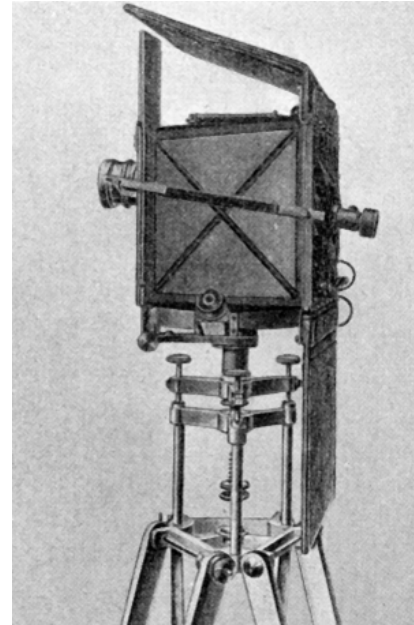


Fig. 18: Photo-theodolites by FINSTERWALDER (1895) and Zeiss Jena 19/1318 (about 1904)

3.2 Aerial panorama cameras

In the beginning of the 20th century aerial photography from motorized aircrafts became technically possible. However, photographic film material was not available off-the-shelf, or the available formats were not satisfactory. Hence, already in the early 1900s the first cameras were developed that consisted of a number of circular arranged lenses in order to widen up the field of view of the camera.

Around 1904 the Austrian Scheimpflug has constructed a camera with seven oblique lenses grouped around one central lens to be used from balloons. The acquired image could be transformed into one central-projective photograph by a special rectifying instrument (Fig. 19).

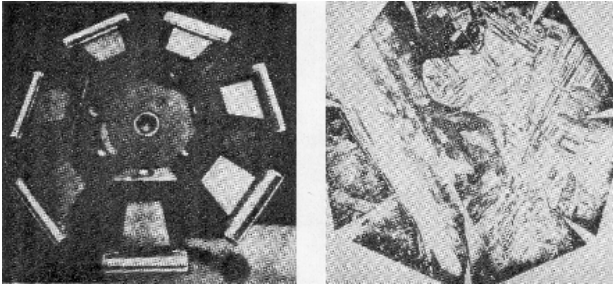


Fig. 19: Eight-lens camera by Scheimpflug (1904) and decomposed image

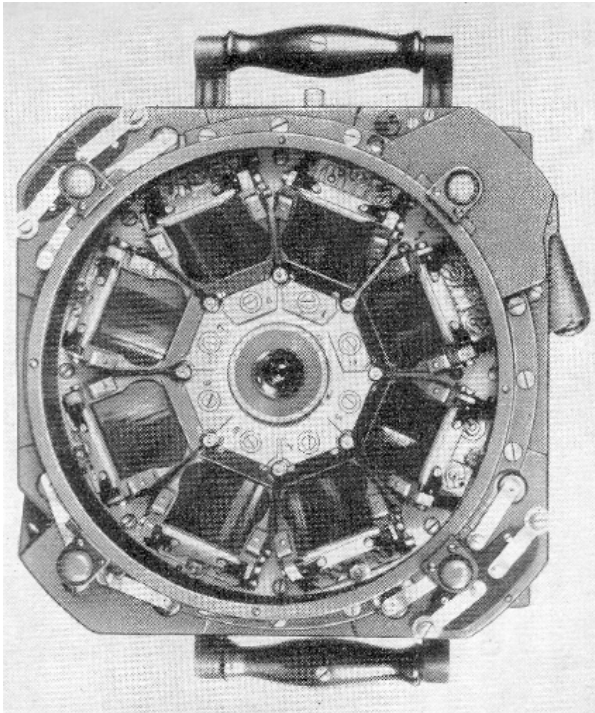


Fig. 20: Aerial panorama camera by Aschenbacher (1929)

In Germany, Aschenbacher had constructed a camera based on 9 lenses (Fig. 20). Careful adjustment of the single lens devices made it possible to create a wide-angle image that could be processed photogrammetrically. Special instrumentation had to be developed and manufactured in order to compile the images by analog principles.

During the second world war and in the following decades super-wide angle panorama cameras have been developed, especially for reconnaissance purposes and small-scale mapping. Some of these cameras were able to observe from horizon to horizon perpendicular to the flying direction. In North America, these cameras became quite popular since these countries had a tremendous demand on small-scale maps due to the huge area to cover (example in Fig. 21).

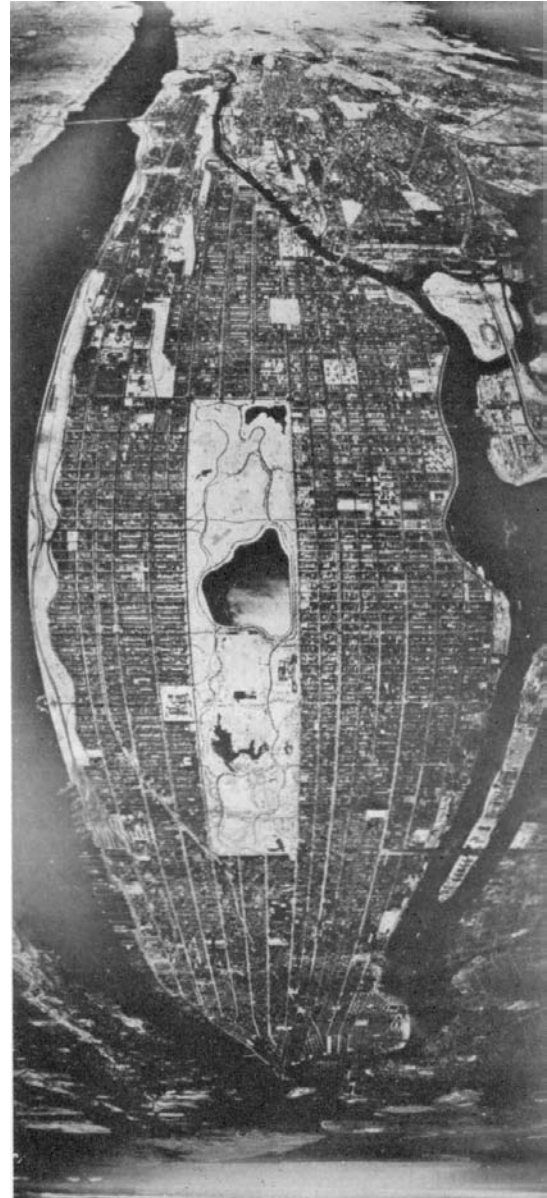


Fig. 21: Aerial panorama image of Manhattan (1949)

In the 1950ies and 1960ies scanning cameras were developed that could image a wide field of view along the viewing direction. Direct-scanning film cameras used a lens that was rotating around the rear principal point while the film was exposed through a thin slit aperture (Fig. 9, Fig. 22). In contrast, cameras with a rotating prism could be designed such that a scan of 180° or even more could be achieved (Fig. 23). Panoramic photographs of both designs were subject to severe distortions due to the scanning principle (Fig. 24). It is overlaid by the motion effect resulting in non-linear distortions. The device were actually pre-developments of the later successfully launched opto-mechanical satellite scanners like Landsat MSS.

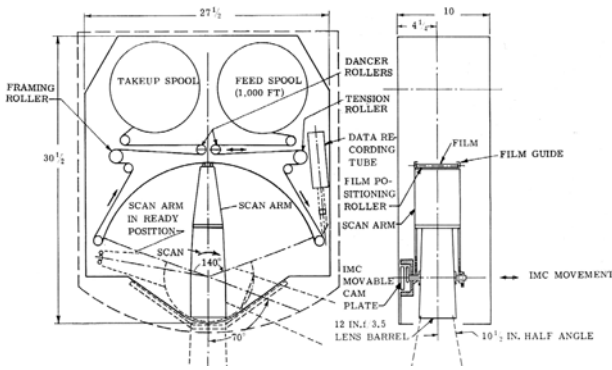


Fig. 22: Scanning principle for aerial panoramic camera with swinging lens

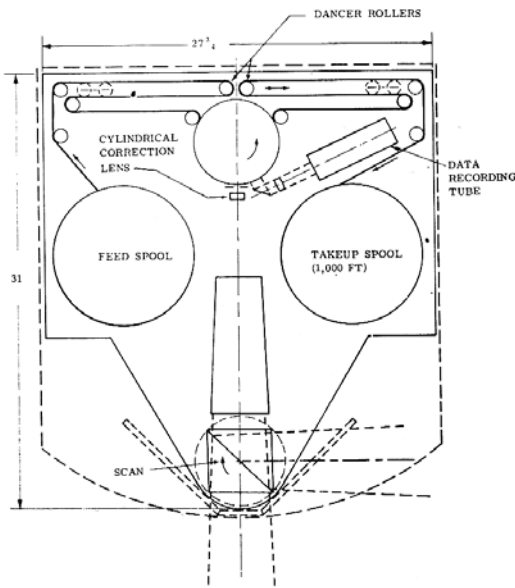


Fig. 23: Scanning principle for aerial panoramic camera with rotating prism

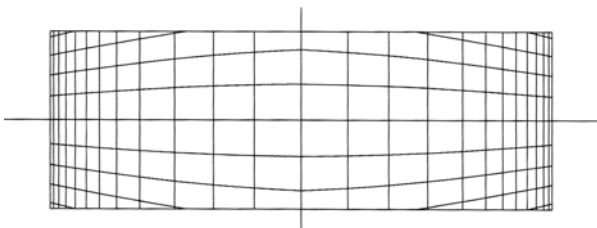


Fig. 24: Panorama distortion due to panoramic scan (Mikhail et al. 2001)

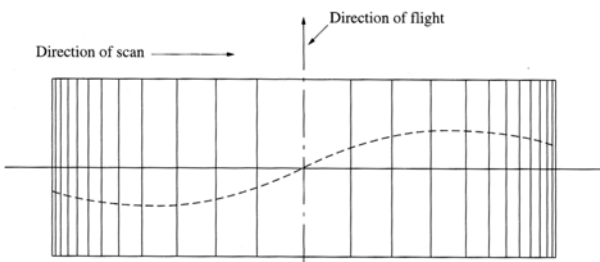


Fig. 25: Panorama distortion due to motion of panoramic camera during scan (Mikhail et al. 2001)

4 DIGITAL PANORAMA CAMERAS

Digital panorama cameras are on the market since about 1990. The broad popularity of digital panorama imagery may be caused by the following reasons:

- Simple panorama stitching software for digital consumer cameras is available
- High-resolution CCD line scanners have been developed for high-quality panorama acquisition
- Mars exploring vehicles have imaged the planet surface by use of panorama cameras that were presented through mass media
- Internet applications and plug-ins are available for viewing panorama imagery
- Increasing use of surveillance cameras on public places, or the interior of buildings

High resolution and image accuracy is of major importance for the photogrammetric use of digital panorama cameras. Both objectives can be reached if the complete imaging geometry is modeled and calibrated appropriately. During the past years several instrumental and mathematical solutions have been developed for the precise application of line-scanning cameras as shown in Fig. 26. Superb color image quality can be achieved, however, high mechanical and optical effort is spent leading to high investment costs.



Fig. 26: Digital panorama line-scanning cameras RotaScan Noblex (left) and KST EyeScan M3 (right)



Fig. 27: Digital camera Kodak DCS 645M mounted on panorama adapter

Alternatively, accurate panoramas can be acquired by single digital photographs. Professional digital cameras with up to 4000 x 4000 pixel are available today. They can be calibrated and oriented by standard methods in order to provide the necessary geometric information for a precise resampling of a cylindrical or spherical panorama image. For image acquisition it is required to mount the camera on a panorama adapter that must be adjusted such that the rotation axis passes the principal point of the lens (Fig. 27).

If the interior orientation of a panorama camera is given, and exterior orientation parameters can be calculated for different camera stations (e.g. by panorama bundle adjustment), photogrammetric object reconstruction can be performed by methods like space intersection. This technique is interesting for the 3-D modeling of interior rooms since very few panorama stations and tie points are required for 3-D processing.

Recent developments in terrestrial 3-D laser-scanning show the potential of combining active 3-D sensors with imaging devices. Reports on state-of-the-art and newest developments are summarized in Luhmann (2001–2004) and Grün & Kahmen (2001, 2003).



Fig. 28: 3-D laser-scanner with integrated camera (Riegl)

5 SUMMARY

The historical review of the development of panorama camera shows clearly that today's attention on panorama techniques has very old roots dating back to the beginning of photography. Early photogrammetric camera developments show principles of panoramic image acquisition since a wide field of view was desired at all times. It can also be shown that the later successfully used photo-theodolites had their origin in panorama cameras.

In aerial photogrammetry panorama images were used mainly for small-scale mapping and reconnaissance in the 1950s to 1980s. Meanwhile remote sensing satellites have replaced these devices.

Recent available high-resolution panorama cameras and panorama generation methods offer an interesting potential for 3-D object reconstruction by all-around views. Hybrid sensor fusion with 3-D laser-scanning is a new powerful tool for single station object recording.

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