SPATIAL INFORMATION FROM IMAGES
(SUMMARY PAPER)

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1. Introduction

It has been 400 years that Galileo Galilei wrote in 1597 his first letter to Kepler in support of the Copernican theory from here, the University of Padova. By constructing the first telescope and discovering with the help of it the mountains on the Moon, the moons of Jupiter and the Sun eruptions, Galilei became one of the forefathers of modern astronomy and surveying, or as it is expressed implicitly by the title of this Tutorial "From Astronomy to Geomatics", he helped triggering a development which turned into a key component of the modern science of "geomatics". This is reason enough to briefly review the history of photogrammetry, before we turn our attention to the major current research issues and developments.

2. A brief history of photogrammetry

Through Prof. G. Konecny, on occasion of his Keynote Speech at the Opening Session of the XVIIIth Congress of the ISPRS in Vienna, July 9, 1996 we learned of the Russian economist Kondratjew, who in 1925 advocated the so-called "wave theory" of economic development.

According to his concept 30 years of economic growth are followed by 20 years of recession, before another growth period of 30 years starts. During the years of recession new technologies are developed ("Need is the mother of invention"), which stimulate the next growth period.

Transferring this theory to photogrammetry we diagnose a surprising coincidence. The invention of photography and the construction of the first metric camera by Laussedat (1851) brought about **planetable photogrammetry**. The mastering of precision optics and mechanics together with the invention of the airplane (around 1900) stimulated **analogue photogrammetry**. The successful introduction of digital computers (around 1945) was a key element in starting **analytical photogrammetry**. And finally, the great progress in microelectronics and semiconductor technology (around 1980) and the related development of powerful new sensors (e.g. CCD cameras) and computers/computer peripherals, allowing for fast image processing, was crucial to the introduction of **digital photogrammetry**.

Today we speak of these different phases in development as "paradigm shifts". These times of change are always accompanied by great worries concerning the future of the profession, but also by high expectations with respect to the new technologies in terms of advancing science and opening the profession new fields of application.

In the **Appendix** we present, without any further comments, a compact survey of the decisive dates, names and achievements in the historic development of photogrammetry.

3. Current problems and solutions

The spatial data environment of today is characterized by fast advancements in the following areas, supported by the related tools/ techniques:

- *Digital sensor technology (optical, microwave):* Semiconductors, microelectronics
- *Automated processing:* Image analysis, computer vision
- *Administration, analysis of data:* CAD technology, spatial information systems
- *Representation:* Computer graphics, visualization, animation

Research and development in these areas generate a very broad, interesting and lively research spectrum, to which many scientists with different backgrounds can successfully contribute.

Among the many current activities we will focus here on a few significant developments in

- *platforms, sensors and processing concepts*

as applied to

- *satellite remote sensing*
- *aerial photogrammetry*
- *videogrammetry machine /robot vision*

4. Platforms, sensors and processing concepts

Satellite remote sensing and digital photogrammetry both brought a remarkable change to our discipline and the way it is performed. Traditional photogrammetry was essentially characterized by the use of one particular type of sensor - a photographic camera, and many diverse processing instruments and methods (analogue stereoplotters of different types, analytical plotters, comparators in mono and stereo, rectifiers, orthoprojectors, point markers, triangulators, various low cost devices, and special application equipment for "non-topographic" and "non-conventional" photogrammetry). In satellite remote sensing and digital photogrammetry we meet however a great variety of sensors (photographic cameras, matrix array CCD-cameras, linear array CCD-cameras, point scanners, laser rangers/ scanners, SAR, InSAR, GPS, IMU, etc.) and a single type of processing system - a digital station, with image processing functions and possible a connected CAD system or GIS. This ultimately also leads to a unification of processing methodology and algorithms. What used to be considered more or less separated areas - satellite remote sensing, aerial photogrammetry, close-range photogrammetry - is overlapping today in methodology a great deal, in terms of sensors applied and of processing tools and techniques used. Differences are found in applications and can primarily be expressed as variations in geometric and radiometric resolution of the images. As far as sensors and platforms are concerned there are differences in emphasis, dictated by the current applications, and shown in Table 1.

Among the many research issues a few are mentioned here, which combine high scientific value in research with the promise of generating relevantnew applications:

- *HighRes optical satellite sensors*
- *SAR, InSAR for DTM, landuse, change detection*
- *Digital airborne sensors*
- *Digital photogrammetric stations*
  Platforms for satellite, airborne, terrestrial data
- *Automated DTM generation*
- *Semi-automated extraction of linear features*
- *Cyber City:Extraction of houses, etc., 3-D modelling, animation*
- *Terrestrial Mobile Mapping*
- *Measurement Robots for industrial quality control, robotics, etc.*
- *Systems for animation and generation of virtual environments*

Table 1: Platforms and Sensors (as of 1996)

Sensor \ Platform	Space-borne	Airborne	Terrestrial
Photo Camera	**X**	**X**	**X**
CCD Matrix Array	(X)	X	**X**
CCD Linear Array	**X**	X	(X)
Point Scanner	**X**	(X)	(X)
Laser Ranger	(X)	X	(X)
Laser Scanner	-	X	**X**
SAR, InSAR	**X**	X	-
GPS	(X)	**X**	X
IMU	-	X	X

X ... Established technology, widely used
X ... Occasionally used, but not fully established
(X) ... Little in use/planned

In the oral presentation comments have been made regarding the status of research and technology in most of these areas; this shall not be repeated here.

5. Conclusions

As major conclusions, drawn from these considerations, we recognize that

+ *sensors* are aiming at increasingly higher resolution, both in geometry and radiometry. This will lead to better results and many new applications. As an example, CEOS predicts 70 earth observation satellites being simultaneously active in the year 2004
+ *multisensor systems* will deliver more reliable results and through the use of various clues automation in processing will become more robust
+ *digital sensors* (CCD, microwave, range scanners) will provide for on-line/real-time processing capabilities and thus extent the range of applications significantly
+ progress in *automation* will lead to more economic solutions
+ progress in *algorithmic development* is slow but steady. Image and scene understanding are key issues to be addressed in the years to come
+ *digital processing systems* potentially allow for new processing technique and new products. Unfortunately commercial developments are trailing far behind the current state-of-the-art in research
+ *remote sensing and photogrammetry* are converging technologies, which, through integration of GIS and CAD capabilities, will finally bring about truly integrated systems.

On the **application side** we see among others

+ a growing need for *3-D urban data* in structured form for applications in telecommunications, environmental engineering, planning, etc. Photogrammetry is the technology of choice to generate this data
+ *Mobile Mapping Systems* (using as platforms cars, trains, helicopters, etc.) recording roads, railway tracks, buildings, street signs, traffic accidents, land slides, earthquake and fire damage, etc.
+ many avenues for close-range applications in *machine and robot vision, medical imaging, animation, virtual reality, etc.*

In order to properly **advance our discipline** we should

+ realize that fast and solid progress today can only be achieved by *cooperating in a transdisciplinary mode.* This will provide all partners with broader perspectives and more powerful solution strategies and will give easier access to new applications. One component of this cooperation is the conduction of joint conferences
+ cooperate in a better way on *professional and organizational level.* e.g. through organizations such as IUSM
+ recognize that *internationalization of R and D* through

programs like those of the European Union, bilateral programs and the impact of multinational companies can provide for interesting new options.

The **impact** of these developments and requirements **on the profession** are manifold, out of which questions arise such as

+ how do we handle the *inflation of data*, in particular images ? Our processing capabilities are already today trailing way behind the data generation rate
+ how does the increased *system complexity* affect our daily work? Do we need more blackbox approaches or rather better educated personnel ?
+ how do we cope with the *competition from neighboring disciplines* ? Depending on our own capabilities, flexibility and attitudes our discipline will either disappear or emerge with greater strength than ever before.

Scientifically and professionally we are living in a very interesting and challenging period of time. The times of Galilei have long gone, when an individual was still capable of mastering the knowledge of the world. Our task of delivering spatial information from images alone is today such a demanding endeavor, that it requires the best talents of our discipline to continuously develop novel approaches for the advancement of our science and profession.

Appendix: Historic development of photogrammetry

15th Century *Leonardo da Vinci*, perspective projection

1726 *M.A. Cappeler*, mapping of Pilatus from hand-drawn perspectives

1759 *J.H. Lambert*, publication of first textbook on descriptive geometry
(Chap. 8: "Freye Perspective")

1839 *J.N. Niépce and L.J.M. Daguerre*, discovery of photography
F. Arago , French Academy of Sciences report: useful fortopographical mapping

1846 Foundation of *ZEISS* company

1851 *A. Laussedat*, ("Father of photogrammetry"), construction of first metric camera, first topomap ("Métrographie")

1858 *A. Meydenbauer*, founder of architectural photogrammetry

1858 *G.F. Tournachon* ("Nadar"), first aerial (balloon) photographs

1858 *J. Porro*, panoramic camera, photogoniometer

1878 *P.Paganini*, alpine mapping, phototheodolite, plotting instruments

Early developments in Italy

1858 *Ignazio Porro*
Inventor of teleobjective
Development of photographic camera (panoramic scenes)
"Porro principle": Photogoniometer

1875 *Military Geographical Institute, Firenze*
Experiments in mapping (Bart glacier, Mont Cenis)

1878 *Pio Paganini, MGI*
110 pictures, Alpine region, 1: 25 000
1880: 1000 km^2, highest Italian alps, 1: 50 000
Phototheodolite (Galileo), → no separate telescope
Invention of plotting instruments

E. Dolezal, ISP founder: "Incontestably, Italy was the country which, thanks to Paganini's work, gained the leadership in photogrammetry and maintained it for a long time".

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1886 *E. Deville*, mapping in Canada

1888 *S. Finsterwalder*, glacier mapping, theory

1889 *C. Koppe*, German textbook on photogrammetry

1890 *E. Abbe*, comparator principle

1891 Stereoviewing with polarization

1892 *F. Stolze*, principle of floating mark

1897 *Th. Scheimpflug*, theory of double projection → instrument

1901 *C. Pulfrich*, ("Father of stereophotogrammetry"), first stereocomparator, measurement of clouds, waves, etc.

Stereophotogrammetry

1838 *Ch. Wheatstone*, formulation of design of a stereoscope

1849 *Brewster*, lens stereoscope

1857 *H. Helmholtz* , mirror stereoscope

1866 *E. Mach, Vienna:* "An application of a stereoscope which is quite obvious but has not been used, would be the estimation or mensuration of spatial quantities"

1896 *E. Deville*, stereoscopic instrument for continuous plotting

1901 *C. Pulfrich*, stereocomparator: stereoobservations + floating mark

1901 *G. Fourcade*, phototheodolite + measuring stereoscope

1903 *S. Finsterwalder*, theory of orientation, mapping from aerial (balloon) photographs, 2 photos Gars/Inn (orientation+intersection took from 1900 to 1903)

1903 *Wright brothers*, airplane

1909 *E. v. Orel,* "Stereoautograph", plotting of lines

1910 *Foundation of ISP,* 4.7.1910 by E. Dolezal in Vienna,
first members: Austria, Germany

1911 *Th. Scheimpflug,* concept of orthophoto/photomap

1911 *E. Dolezal:* "85% of the Earth's surface is topographically unknown, the knowledge depends greatly on vague descriptions of explorers"

1913 *First Int. Congress of ISP, Vienna*

1914-18 *World War I,* promotion of aerial photogrammetry

1915 *O. Messter,* construction of aerial metric camera, "Maltese cross"

1921 *R. Hugershoff,* stereo analogue instrument „Autocartograph"

1923 *W. Bauersfeld,* ZEISS Stereoplanigraph

1926 *Second Int. Congress of ISP, Berlin*
Hey-days of analogue aerial photogrammetry: Mass production of maps, foundation of private companies, public agencies
Otto von Gruber: "He who computes much does not think"

1927 *R. Ferber,* orthoprojection solution

1929 *O. Lacmann,* design and construction of orthorectifier

1930 *Third Int. Congress of ISP, Zurich*
Orientation procedures on analogue instruments
Dr. h.c. of ETH Zurich: Heinrich Wild
Sebastian Finsterwalder

1939-45 *World War II,* promotion of reconnaissance/ remote sensing

1952 *7th Congress of ISP, Washington D.C.*
Extensive analogue mapping on international scale

1952-55 *H. Schmid,* Collinearity equations + Least Squares estimation
D. C. Brown, Matrix calculus + statistical analysis
> Bundle model of analytical photogrammetry
Zeiss, Wild: High precision stereocomparators (PSK, STK)
> Accurate measurements

1955 *R.K. Bean,* USGS, Orthophotoscope

1957 *U. Helava,* invention of Analytical Plotter

1959, 1964 *E. Gigas, Carl Zeiss,* GZ 1 Orthoprojector

1970 *Foundation of CIPA, Paris,* organisation of 15 int. Symposia

1972 *12th Congress of ISP, Ottawa*
Introduction of self-calibration → accuracy improvement, new applications

1972 *Landsat 1,* NASA, Satellite remote sensing

1976 *13th Congress of ISP, Helsinki,* 7 Analytical Plotters exhibited

1980 *14th Congress of ISP, Hamburg,* ISP → ISPRS

1984 *15th Congress of ISPRS, Rio de Janeiro*
Introduction of digital close-range photogrammetry based on CCD cameras

1987 *2-4 June, Interlaken, "Intercommission Conference on Fast Photogrammetric Processing",* first "fully digital" conference

1988 *16th Congress of ISPRS, Kyoto,* Analytical → Digital