FUTURE ORIENTED SCENARIOS FOR CLOSE-RANGE PHOTOGRAMMETRIC INSTRUMENTATION

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1 ABSTRACT

By using a futures analysis method called FAR (Field Anomaly Relaxation) four different scenarios are presented for the close-range photogrammetric instrumentation until the year 2010. Each scenario forecasts a slightly different rate of plausible progress in applying digital and real-time photogrammetric systems within the area of industrial manufacturing. The ideal destination converging the scenarios is found within the implication of perspective photongrammetry.

2 INTRODUCTION

We have presently several alternatives in developing the close-range photogrammetric instrumentation. There already exists analytical plotters equipped with image correlators, mono-comparators with digital gage positioning, metric cameras with area image scanners, servoed theodolites with image sensors and real-time systems with only solid-state video cameras. As seen by us, surveyors, the internal origin for the instrumentation evolution heretofore relies upon a long history in using perspective projection geometry for the optical and three-dimensional point determination in space.

The common external origin for the present technological stage of close-range photogrammetric instrumentation dates primarily back to the fifties and sixties. The recent progress of our instrumentation has been strongly forced by the rapid implementation of modern photonics, electronics and image processing technology. The small solid state imagers have been placed into the optical path of the ordinary surveying instruments and the digitized images are further fed into the image processors for the purpose of automated deriving of the necessary measuring data. Naturally all this progress has been closely due to the the general process of development in micro-electronics.

The question is: Where do we focus, as photogrammetrists, our internal creativity in the nearest future when developing further our instruments?

3 FIELD ANOMALY RELAXATION METHOD

In order to build up any scenarios a forecasting technique called Field Anomaly Relaxation Method (FAR) was applied. The FAR is a morphological method especially developed for describing plausible alternative futures (Mitchell et al., 1977).

The method was initially introduced by Stanford Research Institute and originally adapted to comprehensive societal forecasting. Slightly modified it has been applied later also for futures research in lesser fields (e.g., Seppälä, 1987). It is seemingly helpful in broadening perspectives on a wide range of possible futures. Limitations include the fact that FAR is less predictive than descriptive or analytic. Plausibility judgements are highly subjective.

The FAR-procedure begins with defining normally 6 to 10 critical components of the subject being studied. These components are then arrayed due to possible conditions which are collected to build up a morphological table. The self-consistent sections as temporary snap-shots are defined by combining a single condition from each component area. These snap-shots are strung together into scenarios that seem plausible within the forecast period and the main stages are dated.

For the purpose of forecasting the scenarios for close-range photogrammetric instrumentation the FAR-procedure was here sligtly modified. The number of critical components was limited to only five, each conditioned with four elements. The temporary snap-shots were spanned not only for the coming future but also back to fifties. This was done in order to test the consistency of the morphological table, including the significancy of the choosen components and the relevancy of the conditions defined within each component.

4 MORPHOLOGICAL TABLE

In the following section the morphological table (Table 1) is presented as a list of the technical, scientific and economical components which characterize the different stages in photogrammetric instrumentation activity. The conditions within these critical components are shortly explained by practical examples.

I. Image Acquisition vs. Input Image

A. Momentary / Analog. The images are exposed momentary on photographic materials and the analog photographs are used directly for visual interpretation in stereoplotters.

B. Momentary / Digital. The momentary images are digitized and the interpretation is mainly performed by computer means. The comparators and analytical plotters equipped with image digitizing units and also the satellite imaging systems are included into this category.

Table 1. The morphological table.

CRITICAL COMPONENTS	CONDITION A	CONDITION B	CONDITION C	CONDITION D
IMAGE ACQUISITION VS INPUT IMAGE	MOMENTARY / ANALOG	MOMENTARY / DIGITAL	DYNAMIC / DIGITALLY SCANNED	DYNAMIC / MECH. SCANNED
TRENDS IN IMAGING VS PROJECTIVE PROCESSING	ANALOG IMAGING / ANALOG PROCESSING	ANALOG IMAGING / DIGITAL PROCESSING	DIGITAL IMAGING / OFF-LINE PROCESSING	DIGITAL IMAGING / ON-LINE PROCESSING
PRIMARY APPLICATION	TOPOGRAPHIC MAPPING	SATELLITE MAPPING	SATELLITE TOPOGRAPHY	INDUSTRIAL PRODUCTION
RESEARCH ACTIVITY	PERSPECTIVE MATHEMATICS	ANALOG MATHEMATICS	DIGITAL MATHEMATICS	3D-IMAGE MATHEMATICS
ECONOMY VS TECHNOLOGY PROGRESS	GOOD / FAST	GOOD / SLOW	POOR / SLOW	POOR / FAST

C. Dynamic / Digitally Scanned. The dynamic images are gathered having a continuous access by digital means to the entire scenery covered by the image acquisition devices. The ordinary, firmly mounted full frame video cameras where the frames are digitally scanned envisage best this category.

D. Dynamic / Mechanically Scanned. The digitized scenery is dynamic but the scanning of the scenes is performed mechanically like in servoed theodolites or in cameras with scanning imager chips.

II. Imaging vs. Projective Processing

A. Analog Imaging / Analog Processing. The analog stereo images are processed by analog means as in the analog plotters.

B. Analog Imaging / Digital Processing. The analog images are processed by digital means like in analytical plotters. Also the analog and digital theodolites are included here.

C. Digital Imaging / Off-Line Processing. The digital images are processed partly on-line but the object space coordinates are derived off-line. Already realized.

D. Digital Imaging / On-Line Processing. The projective equations are processed continuously on-line according to the image frame frequency. Not yet realized.

III. Primary Application

A. Topographic Mapping. The ordinary and main task for land surveyors as topographers and mainly performed by plotting aerial stereo images.

B. Satellite Mapping. Primarily used for small-scale mapping by means of multi-spectral images and digital image interpretation. Commonly known as remote sensing applications.

C. Satellite Topography. The present stage of digital stereo plotting by means of high-resolution satellite images.

D. Industrial Production. The wide range of different kind of engineering survey applications. When applied for quality control, also closely confronted to the modern manufacturing automation.

IV. The Focus of Research Activity

A. Perspective Mathematics. The research for complete understanding of the physical behaviour of projective or even perspective image formation. Actual for surveyors already since more than a hundred years, but becoming again popular due to the complicated machine vision problems.

B. Analog Mathematics. The construction of analog plotters once already solved by mechanical or optical-mechanical means. The future is unknown.

C. Digital Mathematics. Realization of projective transformation by digital means like in analytical plotters. The extension of the mathematical model to most comprehensive conformance with the physical model.

D. 3D-Image Mathematics. Three-dimensional image processing in order to build up space images of objects and the entire scenery. A critical and thus popular problem for dynamic machine vision applications.

V. Economical Circumstances vs. Technological Progress

This component relates to the economic cycles according to Kondratjew as it has been presented by Konecny (1985). The economic development occurs in historical cycles of about 50 years the last minimum having incidented around 1950. The economic growth is always initiated by new technologies also in cycles of about 50 years. After 30 years of economic growth there follows a crisis. During this crisis new technologies are developed, which after 20 years of recession generate a new growth. According to this the sequential quarters of the ongoing economic cycle beginning from around 1950 run approximately as follows:

A. Good / Fast. Limited economic prosperity but the progress of technology (electronics, computers) still being strong.

B. Good / Slow. General economic prosperity with the full implementation of recently new technologies.

C. Poor / Slow. Recession begun around the mid of seventies. The quarter is for late implementation of known technologies whereas we still can't really see the new inventions.

D. Poor / Fast. Late recession during nineties before a new growth which begins around 2000. The proper time to increase the research activity due to new inventions in order to push on a new implementation swing.

5 SCENARIOS

5.1 Photogrammetry in general

As an introduction to the future scenarios of close-range photogrammetric instrumentation a scenario for photogrammetry in general is first presented. This consists of four successive periods related to the different quarters of the ongoing economic cycle. Thus three of them are projected back onto the progress of photogrammetric instrumentation since 1950 and the fourth one is a forecast of the near future.

The combination of the uppercase letters within each section indicates the chosen conditions of the five critical components as stated in the morphological table. The conditions are in order according to the table and there is one choice for each component respectively.

The scenario for photogrammetic instrumentation in general is:

i. Around 1950 - 1962: AAABA. The quarter of final implementation of analog aerial photogrammetry. The main applications are within topographic plotting over large areas by aerial analog plotters. The research on analog processing of stereomodels including analog triangulation is popular although the pure analytical models are already in a developing stage on electronic computers. The time is for limited economic prosperity but progressing implementation of basically known technologies.

ii. Around 1963 - 1974: ABACB. The main progress is found within the digital processing of analog image coordinates. Both aerial block triangulation and analytical plotting are becoming professionally practicable due to the active research and development efforts. The principal application is still the economic production of topographic maps by means of growing amount of analog plotters. The time is for good economic prosperity but basically and only for wider implementing of seemingly experienced technologies.

iii. Around 1975 - 1987: BCBCC. The small scale thematic mapping is becoming the major application due to the wide propagation of satellite images. The momentary digital images are processed off-line by means of ever growing computer capacity. The projective mathematics is actively researched in order to complement the physical models by digital means. The economy is declining. The progress of implementing old technologies is seemingly recessive but already aware of new inventions, like neural processing or high-temperature supra-conductors only as examples.

iv. Around 1988 - 2000:

a) BCCCD. First, the topographic mapping from satellite images becomes practicable in medium scales. This is due to the better accessibility of satellite stereo images and related instrumentation. The foreseen universal applications of Geographic Information Systems generate a rehabilitation within the traditional surveying instrument manufacturing markets.

b) BDCDD. Next, the progress of technology becomes fast again and results in the on-line processing of digital images like by means of parallel processors and effective stereo matching algorithms. The photogrammetric society concentrates the main developing activities on airborne instruments applied for real-time monitoring or topographic mapping in large scales. Still the majority of the users keep on in large-scale plotting with their existing analytical instrumentation. The wider implementation of the real-time airborne photogrammetry is possible first during the new economic cycle, which begins around 2000.

5.2 Close-range photogrammetric instrumentation

For close-range instrumentation four different scenarios are outlined and spanned until around 2010 (Figure 1). Each scenario begins with a short description of the present state of respective branch. The forecasts imply that the majority of the applications will be on the industrial manufacturing automation. Whilst the economy is still more or less recessive in the first half of the scenario time it becomes prosperous again around 2000. The technology progress remains fast all the time.

The scenarios for close-range photogrammetric instrumentation are:

5.2.1 High-Accuracy Photogrammetry

i. BCDCD. The comparators have been automated for digital pointing and correlation of large-format analog metric images (e.g. Brown, 1987; Helava, 1987). Complete sets of instrumentation including advanced software have been installed already for periodic inspection of industrial tooling. The achieved accuracy rates are proportionally 1 : 100,000 or better (Fraser, 1988).

ii. BDDCD. The systems are further developed by implementing new and more efficient on-line image and statistics processing components. The real impacts are evidently more on the high reliability by means of flexible trouble shooting than on reduced costs when using the systems.

iii. DDDCD. The comparators are partly removed from the systems and the images are dynamically scanned and directly digitized in the metric analog cameras (e.g. Albertz, 1986; Wester-Ebbinghaus, 1987). Meanwhile, these already experienced cameras have been under active development during several years. The first firmly mounted systems are installed for continuous monitoring and inspection of the industrial objects at the line-ends of automated factories generally. There still exists a majority of comparator-based periodic and off-line inspection installations within the aircraft and space industries.

iv. DDDDD. The research activity has been directed more towards dynamic and three-dimensional image processing due to the mechanically scanned and digitized metric cameras. The strategy implies a growing need for momentary and complete modelling of industrial objects during different stages of manufacturing processes. The systems become practicable due to the advanced image processing components. The first reference installations are made already before 2000.

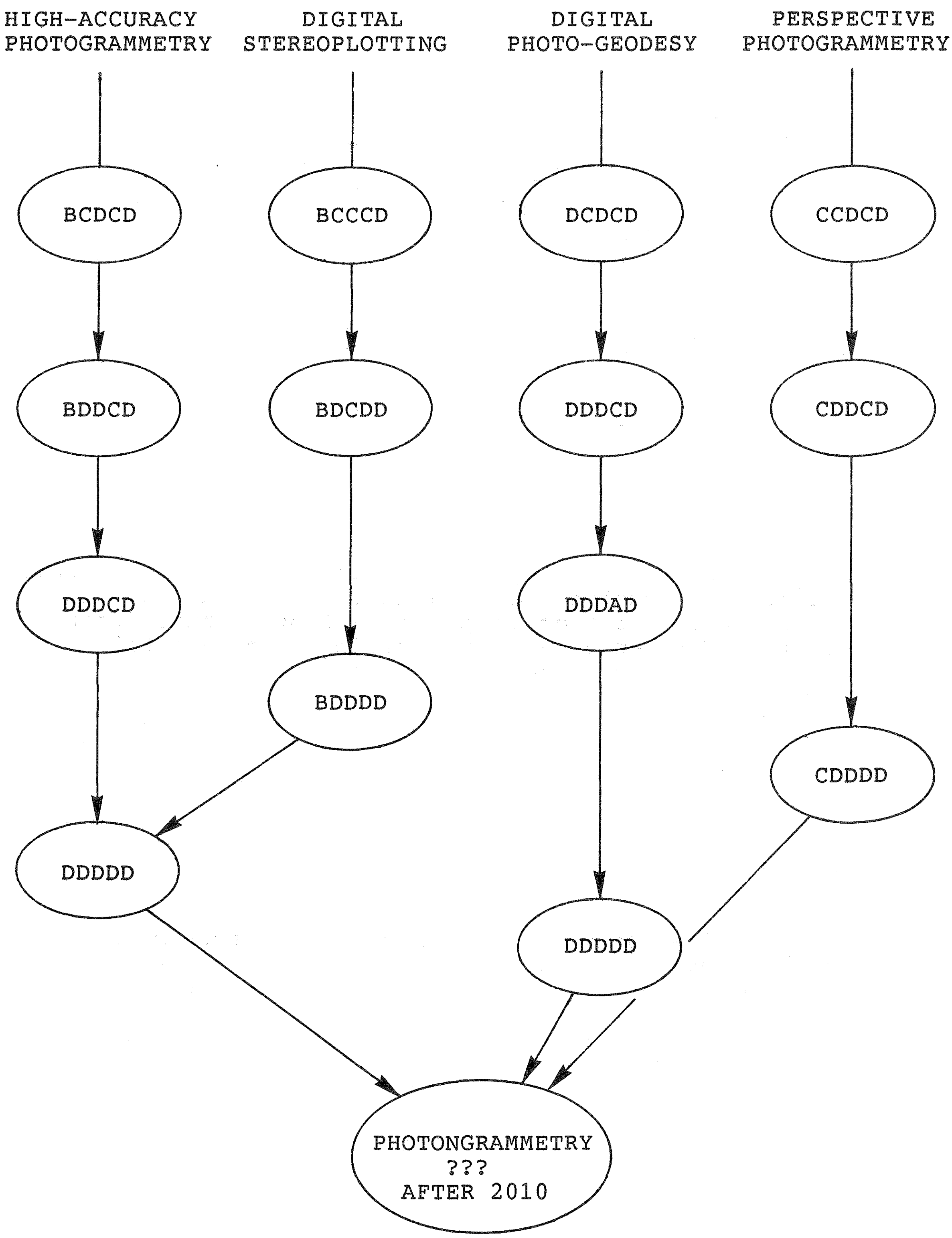

Figure 1. The scenarios for close-range photogrammetric instrumentation.

5.2.2 Digital Stereoplotting

i. BCCCD. The recent possibilities to acquisite satellite stereo images has generated a growing need of digital stereoplotters. Principally the idea has been known already for several years and some prototypes have been under development (e.g. Sarjakoski, 1981; Albertz, 1986). The analytical plotters are first used for industrial measurements where the momentary analog images are processed partly by digital means (Schewe, 1988).

ii. BDCDD. The progress is further supported by implementing more efficient on-line image processing components into the systems. The main markets rest still on the satellite topography applications although the reference installations already exist on industrial side. The primary application is the digital modelling of industrial objects in general. The competition within manufacturing process applications is hard because of the wide propagation of both real-time and comparator-based photogrammetric systems.

iii. BDDDD. The new strategy to propagate the use of digital plotters in idustrial applications relies on the replacement of analog image memories by dynamic digital images. Incidentally, the scenario of the digital steroplotting coincides with the scenario of high-accurate photogrammetry before the last snapshot DDDDD. There still remain the applications of digital plotting partly operated by human means within the area of satellite topography.

5.2.3 Digital Photo-Geodesy

i. DCDCD. First servoed digital theodolite systems have been already equipped with inside mounted imager chips (e.g. Gottwald et al., 1987a and 1987b). These high-accurate systems have been primarily developed for real-time engineering survey parallel to above mentioned comparator-based photogrammetric systems. The first installations exist within the automobile industry.

ii. DDDCD. The systems are further developed by implanting more efficient hardware and software for image processing. Problems caused by the temporal instability of the instrument and object set-ups are solved by sequential check procedures. The rapid growth of the number of istalled systems, and predicted by the market analysts after the first successful reference installations, is still limited by efficiently propagated comparator-based photogrammetric systems.

iii. DDDAD. The first compatible and thus practicable installations for high-accurate applications are among the dynamic monitoring of three-dimensional object deformations and the tracking control of remotly moving objects. The new strategy is also leaning upon a growing research of perspective projection mathematics for the purpose of dynamically process the scanning images.

iv. DDDDD. The photo-geodesy systems are becoming closer to the dynamic photogrammetric systems. The absolute encoding of the rotation angles is partly replaced by the flexible encoding of the movements relative to the fixed check figures locating in the object space scenery. Because of the complex algorithms of perspective projection mathematics the straigthforward new developments lead to a wider implementation first after 2000 during the next economic growth.

5.2.4 Perspective Photogrammetry

i. CCDCD. The real-time photogrammetry has already become an active area of basic research within the society and is primarily concentrated to the geometric processing of off-line images and to the electronics of image forming components (e.g. Grün, 1987). The first stand-alone real-time photogrammetric systems have been already installed for reference purposes (Haggrén et.al., 1987). These systems in combination with advanced geometric modelling software are actively marketed for manufacturing automation applications.

ii. CDDCD. The primary limitation is the seemingly pure resolution of the solid state imagers. This leads first to larger image scales and multi-station imagery and shortly later to the implantation of advanced imager technology with higher resolution in the system. Simultaneously the systems are also enforced by more efficient on-line image processing capacity. The nominal accuracy rates practically achieved are already proportionally 1 : 50,000 or even better. The first operational systems are installed in automated factories, where they are hierarchially procedured in accordance with the manufacturing processes.

iii. CDDDD. The advanced research on three-dimensional image processing results in systems running without external targetting of objects. The growing amount of installed photogrammetric systems within the manufacturing industry leads incidentally to new principles in designing new factories and their production processes already before 2000. The cameras acting as permanent gages and perspective machine eyes are spread all over the assembly lines. They are strictly organized in order to fulfil the various requirements which are dominant to the control activities in different phases of industrial production processes (Haggrén, 1984).

6 CONCLUSION

The scenarios and the plausibility judgements presented here are - and as stated already before - merely subjective and don't tend to be complete in describing the different snap-shots. Thus they may be treated more as rare examples and alternative results when applying the modified FAR-method than as personal statements. The FAR-method proved it's efficiency in opening ones eyes and it will potentially force everyone to generate his own futures analyses. The FAR-process also hopefully helps us to focus our creativity into the areas which are relevant to us as photogrammetrists.

Anyway, according to but also in spite of the above scenarios there exists an evident trend in close-range photogrammetric instrumentation. The scenarios converge more or less rapidly in real-time constructions where the dynamic images are directly scanned in order to produce a continuous flow of three-dimensional control information of industrially manufactured objects. Only the strategies differ from each other depending on the presently existing technological origins respectively.

Conclusively the common need for all these treatments within the photogrammetric society will be the active reasearch on geometric processing of three-dimensional digital imagery and this should further be supported by new developments in dynamic perspective mathematics. We are coming closer to the optical photogrammetry or better to say - closer to the perspective photo<u>n</u>grammetry.

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