

25 Years of Contributions by INPHO to Advancement in Photogrammetry - What is to come next?

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ABSTRACT

A brief review is given about the transition to computational methods in photogrammetry during the 1970s and about the initial contributions from the Photogrammetric Institute of Stuttgart University. They motivated the foundation of Inpho company for the development and marketing of photogrammetric software programs, aiming at high level performance and innovative products. The company established itself successfully during the first 20 years as a reputed software provider of powerful programs for blockadjustment and digital terrain models in particular. The recent years are characterized by extended performance of the software systems, including utilization of GPS and IMU data and the automation of digital processing systems, and by a strategic re-orientation to become an overall systems provider. Inpho company looks forward to maintain and perhaps expand its field of competence and its market position in the future.

1. INTRODUCTORY REMARK

I have been asked to give this short presentation on behalf of Inpho company which is a software company for photogrammetric data processing programs, located here in Stuttgart. It is a partner of the Photogrammetric Week consortium and takes part in the afternoon demonstrations. I myself am not nor have I ever been a member of that company. But I have founded it 25 years ago, in 1980, and have since maintained consulting functions.

2. THE EVOLUTION OF COMPUTATIONAL METHODS

Let me briefly recall the situation of photogrammetry, after I had become professor in photogrammetry and surveying at Stuttgart University in 1966 and had founded the Institute of Photogrammetry there. It was just the time when the application of digital computers became feasible, although still in vague anticipation only. Up to that time universities have had no substantial impact on the development or performance of photogrammetry. The operational concepts used to be set by industry, via the design and use of instruments which remained of analog type for some time to come. The only exceptions at the time were the stereo-comparator and Helava's analytical plotter. But in Europe stereo-comparators were not used in practice outside universities, and disappeared soon. And practically nobody knew here what to expect from the analytical plotter. It took more than another 10 years until it developed into the major universal photogrammetric instrument.

I had become familiar with the first computers at the ITC in Delft, The Netherlands, where I had worked for 8 years. We had there the clear anticipation that computational methods were needed and were possible in photogrammetry, and that they would not only be useful but would thoroughly change the whole discipline. Today we say that computers set off a new paradigm for surveying and photogrammetry. Computational methods would process, refine, and integrate measured data, relatively independent of the actual measuring instruments.

As a side effect it was expected that computational methods would give universities a completely new role in the development and the status of our field. It must be recalled that at the time no

software industry was existing at all. And it still took years until our traditional instrument industry would understand the fundamental changes to come, in the course of which analog photogrammetry would disappear.

We started in Stuttgart right away with the development of powerful blockadjustment programs for aerial triangulation. Other institutes did the same, but we had a certain head start. Computational blockadjustment had soon an enormous impact on photogrammetry, by greatly improving the accuracy and the economy of aerial triangulation, the latter via the enormous saving of ground control points. The direct technical problem was the solution of large systems of linear equations with thousands of unknowns, as we aimed from the beginning at handling large blocks, which had not been common previously. We had, like others as well, experimented with iterative solutions (e.g. conjugate gradients), but abandoned them soon in favor of direct solutions. I remember that I approached quite naively our university computing center, expecting that they would have programs for solving systems of linear equations. They had, but none went beyond 100 unknowns. So we had to develop such programs ourselves, with the additional difficulty that even the Control Data 6600, one of the largest computers at the time, had only a for us usable core storage capacity of 50 K (!). Nowadays one cannot make students understand any more what were the actual difficulties. Anyway, 3 years later the first tests with photogrammetric blocks were made. They turned out to be extremely successful, much more than originally expected. Block adjustment provided quickly a great jump in the practical performance of photogrammetry. And our theoretical studies about the distribution of ground control points and their influence on the resulting accuracy of blocks gave a solid basis for the planning and prediction of projects. I do not have to go deeper into the matter, as all is history by now. Blocktriangulation has become a standard procedure. But at that time, in about 1970, it was a great challenge, and the results were met enthusiastically. We are still somewhat proud that our institute in Stuttgart was able to successfully push the frontline of the development, to which naturally other institutes and institutions contributed as well.

At the same time we developed at Stuttgart University our first program SCOP for the generation of digital terrain models. It was laid out right from the beginning for large sets of data as could be expected from photogrammetric spot height capture, reaching clearly beyond conventional tacheometry. It was another innovative attempt to advance basic concepts by utilizing powerful computational methods. With the DTM software we made the experience, for the first time, that the mathematical core of the program took only about 20% of the total system, the rest was needed for data handling and ensuring the quality performance. It was our concept from the beginning that the DTM would become a separate new product for terrain description. But the initial key issue was the computational derivation of contour lines. It is interesting that we had great resistance from the cartographic world. At that time most cartographers were not ready to accept computationally derived contour lines, being fixed on the strong belief that designing contours is an act of creative art performed only by human specialists. It needed extensive tests in order to show that the quality of computationally derived contour lines depends in first instance on high performance software and on the quality, distribution, and density of the input data. With enough spot heights, additional break lines, and characteristic features we were able to demonstrate that contour lines could be obtained which were virtually identical with manually drafted contour lines.

The described developments took place at the Stuttgart University Institute. In the 1970s the universities were in fact the only institutions which could develop computer methods and software programs. At that time software industry was not yet existing.

That situation changed gradually during the decade. The first European analytical plotters appeared after 1976. Numerical methods had started to become accepted and efficiently applied in practice. Having observed the changing scene I myself had realized that the development of computer methods for practical application would become a standard task of industry and would not any longer constitute a basic task of universities. They should concentrate on fundamental scientific development and evaluation studies and leave the turnover into practical application to the software companies to come. So, we decided to found the Inpho company in 1980, for the development and marketing of photogrammetric computer programs. The relationship with the university, which was still needed, was to be maintained by contracts. In view of the successful previous development the new Inpho company intended strongly to operate in the front line of high quality innovative developments. And that intention has become the trademark of the company. Several of the programs have been the first of its kind.

There was a second reason for founding a private company. In the 1970s our local ministry had become influenced by the ideology of the '68 student revolution. As a result contacts of university institutes with industry and application agencies became suspicious. They were nearly forbidden and each project was supposed to be applied for and approved. That tendency was most annoying and certainly counterproductive for all engineering disciplines. It did not last very long. Today the pendulum has swung back completely, and universities are not only allowed but in fact encouraged to acquire money and contracts from outside as much as possible. This goes again too far, in my opinion, as university institutes now can compete in unfair ways with software industry by producing mere application programs, beyond any claim for thorough research.

3. INPHO, THE FIRST 20 YEARS

Let me now briefly sketch the first 20 years of Inpho's development. As mentioned, the company was set for high performance innovative developments which were intended to strongly push the practical application of photogrammetry by powerful computerized methods. A number of successful steps can be distinguished which have worked very well:

- The first successful software products were the programs PAT-M and PAT-B for blockadjustment with independent models and bundles, extended in particular to robust adjustment for automatic blunder detection and to include GPS camera positioning data. There was initially a certain rivalry between the independent model method and the bundle method. Only when after 1980 the analytical plotters became widely applied the precise measurement of image coordinates became convenient, which moved the bundle method to standard application. By the way, the PAT-M program for independent models had been designed from the beginning to handle blockadjustment with auxiliary statorscope and APR data, together with object conditions (e.g, water level constraints) which greatly saved vertical ground control points for medium and small scale photo blocks. It was again an example of innovative development and specialized performance.
- Another important step was the application of self-calibration by additional parameters for the automatic correction of unknown systematic image errors. That method finally pushed the bundle method to most remarkable levels of accuracy performance. It opened the practical application to cadastral photogrammetry on the 3 micron level.
- Another success-program was SCOP for digital terrain models. The previous first version was completely reprogrammed at Inpho and particularly adapted to the hard specifications of the German road administration which required combined input of photogrammetric and tacheometric data and rigorous consideration of complex networks of breaklines.

In the meantime the first investigations about digital image matching had taken place at the University Institute. Actually the method of least squares image matching was re-invented. It was found out later that Ukki Helava had previously used the method, but had abandoned it because of its small convergence radius. Anyway, Inpho used the method in its InduSURF program for the automatic digital measurement of car bodies. It was the first nearly fully automatic system for the digital survey and description of an industrial object. The Volkswagen company used it successfully for the design of its car models, for quite some time.

A few years later Inpho developed the MATCH-T program, on the basis of least squares image matching and feature matching of digitized imagery, and with the side-condition of extremely dense terrain coverage by elevation points. It was a hard struggle to bring down the originally long computing times for the automatic generation of dense digital terrain models to an economically acceptable performance. Refinements for handling breaklines and other special terrain features had to be considered. But a highly satisfactory level of performance was obtained which was proven in several international tests.

Towards the end of the first decade of Inpho's activities two important sensor developments took place. The first was airborne GPS positioning. At the university institute the first tests and experiments were made in 1988, with most promising results. Relative camera positioning accuracies in the order of 10 cm were obtained. Inpho was the first company to implement GPS data into block adjustment. It gave aerial triangulation another push by reducing the required number of ground control for even very large blocks to only very few points, or even none at all. The anticipated success of the method motivated Inpho to carry out a considerable number of practical pilot projects, in cooperation with different photogrammetric production companies, in order to prove and demonstrate the general power of the method under practical conditions of application. The PAT-B program for bundle blockadjustment with GPS positioning data was soon supplemented by the preprogram SKIP for processing the raw GPS data.

In the meantime the University Institute of photogrammetry had begun to look into the method of airborne laser profiling, the second sensor development. Initially only vertically pointing laser profilers were available, with very low measuring rates of about 100–200 Hz only. Side-scanning lasers had not yet been developed. Nevertheless, the first profiling tests in 1988 demonstrated the potential application for terrain measurements in forest areas, for which no other method was feasible. The future extension to airborne laser (lidar) scanning was obvious. The subsequent development of equipment and software for lidar scan application took place in specialized companies (like Topscan, founded by 2 of our university people, after their Dr. promotion). For that reason Inpho integrated lidar data filtering in its SCOP++ software (developed at the University of Vienna, Prof. Kraus) only very much later, when finally the data processing and DTM generation could be separated from particular equipment specifications.

In 1996 the program MATCH-AT was launched for automatic aerial triangulation measurements in combination with blockadjustment. It operated on digital workstations which had gradually come into the photogrammetric scene, replacing the analytical plotters. The program solved for the first time the automatic selection, the transfer, and the measurement of tie-points as input for the online blockadjustment with large clusters of tie-points. It was another essential performance step into digital photogrammetry.

From computational to digital photogrammetry, contributions by INPHO

<i>University Stuttgart</i>	<i>INPHO GmbH</i>		
research	component supplier	system provider	
computational methods coordinate photogrammetry first programs for - AT, - DTM tests accuracy studies 1970	software for - AT-blockadjustment - with GPS/IMU - self-calibration - robust adjustment - DTM 1980	digital systems digital stereo-plotter DAT/EM Vexcel Scanner automatic AT automatic DTM generation + LIDAR filtering large DTM Editing orthophoto generation orthophoto mosaicking 2000	integrated sensor data processing object extraction 2005

The main milestones of INPHO's history

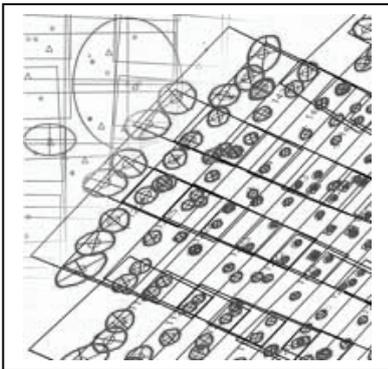
1980	- Foundation of INPHO GmbH, Stuttgart, Germany by Prof. Fritz Ackermann - Activities in aerial triangulation (PATM, PATB) and hybrid DTM modeling (SCOP)
1985	- First developments on area-based digital image matching for applications in industrial surface measurement (InduSURF, MATCH-I)
1991	- First products for GPS-supported aerial triangulation (PATB+SKIP) - Introduction of automatic DTM generation (MATCH-T) based on feature-based image matching
1996	- Introduction of automatic aerial triangulation (MATCH-AT)
1999	- Start of cooperation with Stellacore on orthophoto mosaicking (OrthoVista)
2000	- INPHO turns into a full photogrammetric system supplier and completes its portfolio by own developments on ortho-rectification (OrthoMaster) and by products from DAT/EM Systems International (Summit Evolution) and Vexcel Austria (UltraScan 5000) - INPHO Technology Oy (former X-Position), Espoo, Finland becomes a 100% subsidiary of INPHO
2001	- Introduction of semi-automated 3D building extraction (inJECT)
2002	- Introduction of true-orthophoto capabilities in OrthoMaster and OrthoVista
2003	- Introduction of robust LIDAR filtering (SCOP++) in cooperation with Technical University Vienna
2004	- Introduction of new DTM editing station with stereo capabilities (DTMaster)
2005	- Foundation of inphoUSA, Inc., Baton Rouge, LA, USA as a 100% subsidiary of INPHO

In looking back it can be stated that Inpho had developed very well during the first 20 years of its existence and established itself successfully as a reputed company with generally applicable software products of high quality and innovative nature which have substantially contributed to the fast evolution of photogrammetry by computational and digital methods. The philosophy to provide high level innovative working methods had succeeded very well. Inpho marketed its software to end-users directly, but also had OEM distribution via partners. However, Inpho was essentially a component provider as the products mainly covered certain important components of the photogrammetric workflow.

4. THE RECENT YEARS

At about after 1995 the industrial scene of the instrument manufacturers and their concepts started to change, as well as the application and the market scene. It became evident that Inpho had to alter its previous philosophy and move from a component supplier to a photogrammetric systems provider.

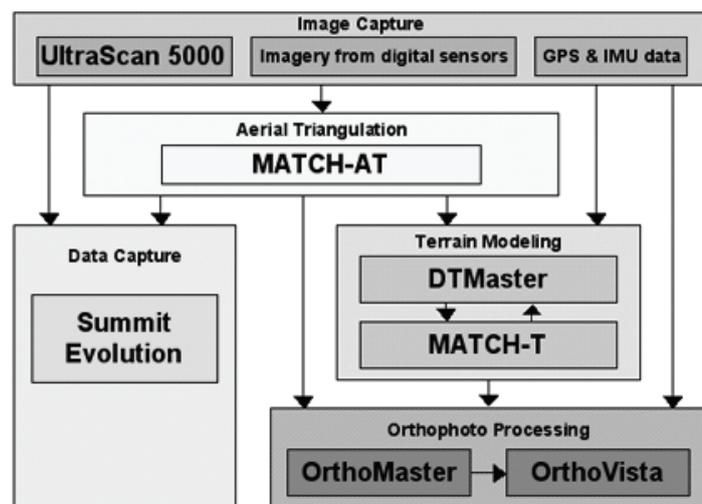
This meant in first instance, as far as software products are concerned, new and integrated means for effective and versatile orthophoto production programs. The present programs OrthoMaster and OrthoVista are the results of such efforts. They cover the whole range of practical orthophoto production, including fast rectification, color balancing, handling of very large orthomap systems, and seamless mosaicking. They represent today a major product line of Inpho.



Along the same philosophy also the PAT programs for blockadjustment had to be reconsidered, which had served very well for nearly 30 years. They were dropped in favor of the completely new inBLOCK program for universal blockadjustment, which includes GPS and IMU data and robust adjustment, and can display graphs for universal accuracy and reliability assessment.

In addition to new internal software developments it became advisable to look for a partner company in order to include interactive digital data capture and cover a larger range of the photogrammetric workflow. We found a partner in DAT/EM Systems International from Anchorage. Their digital stereo-plotter Summit Evolution became our universal data capture equipment into which our software components were integrated to achieve a smooth and highly automated workflow, concerning in first instance data capture, automatic

INPHO's digital photogrammetric workflow



aerial triangulation and orientation, terrain modeling and orthophoto generation. The cooperation has worked very well, to the benefit of both partners, who have agreed to sell each other's products. Another agreement was reached with Vexcel Austria, to have also their reputed image scanner Ultra Scan 5000 in Inpho's total concept. Digital cameras were left outside, although there had been some ideas and suggestions for a digital camera of our own. But it is clearly intended that Inpho's processing software would be able to handle data input from any digital camera, in combination with GPS and IMU data.

Besides, it has been as standard task to continuously update and refine the performance of practically all software programs. The latest examples are new editions of the MATCH-T program and the SCOP++ program for DTM generation. These programs are demonstrated in the afternoon sessions of this Photogrammetric Week. The new features concern for instance DTMs from multi-overlap blocks, abandoning the previous model by model treatment. Particularly effective is the new program DTMaster for editing the new generation of large DTMs which refer to the extremely large amounts of lidar data with the enormously dense distribution of terrain points. In that context also the storage, handling, and administration of very large nationwide DTM and Orthophoto systems has been given close attention.

Inpho has certainly made severe efforts to extend and modernize its product line in order to be prepared for the future changes to come. The technical developments went more or less according to plan. But there was a short period where Inpho had some difficulties. It had to do with an external event, namely the fusion of Intergraph with the photogrammetric section of Zeiss Oberkochen, resulting in the foundation of the ZI-Imaging company in 1999. Up to that fusion Inpho had licence agreements for MATCH-AT and MATCH-T with Intergraph and one for Match-T with Zeiss. These relationships broke down, due to the decisions of the ZI management, and had to be compensated by intensified efforts. It was in fact the occasion for moving Inpho to the system provider strategy. It operates now on a different platform.

It is perhaps symptomatic for a small independent company like Inpho that from time to time the strategic situation is affected by external events and plans, which may require strategic reactions. It is therefore not surprising that during the past years Inpho has been approached by other companies to be bought or go into fusion or other forms of close cooperation. But none of these cases could be agreed to. Inpho wanted to remain independent and self determined. That attitude reflects partly the assessment of our overall status and the intention to retain our experienced and specialized staff. Thus, Inpho has maintained its position and now operates on the basis of a complete integrated package of high performance products which are highly competitive on the market. Therefore the company looks forward with considerable confidence, at least as far as the near future can be foreseen.

5. A LOOK INTO THE FUTURE

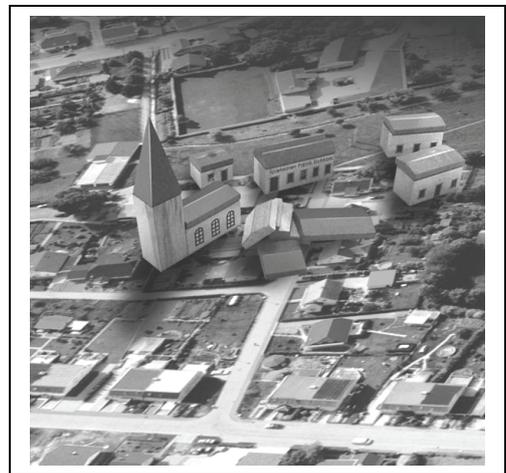
I am supposed to talk also about the future, although I hesitate very much. The simple reason is, that I do not claim to know the future. And with regard to my personal attitude, after 13 years of retirement, I am tempted to quote the late Professor Thompson from the University college London. Towards the end of his official terms he said once that he cannot understand that he is asked all the time about the future of photogrammetry, because at his age the psychological attitude is not actively oriented towards the future any more, and any major changes can only be to the worse. I

have the same feeling myself. I am not interested personally nor do I believe in long term predictions, in view of the acceleration everywhere. I consider the management of this Photogrammetric Week very courageous, trying to look 25 years ahead. I shall certainly listen most intently whether the speakers in that section will be able to meet the challenge. And, who knows, by Friday this week we may be enlightened or become at least somewhat wiser about what to expect in 2030.

But, of course, a number of statements about the expected future can be made, at least for a range of some years to come. In that case one may extrapolate to some extent from the present situation. It is particularly important for a company like Inpho to look ahead and to prepare itself in time for future changes, in order to maintain its field and its position of competence. That is a common feature for the present situation of industry in general. The changes are more rapid than in former times, and one has to prepare for and adapt with ideas in time.

Looking into the future we must distinguish between the expected effects of the technology development and those of the market and business scene. It is perhaps relatively easy to predict the immediate continuation of the technology status:

- There is in first instance the further automation of feature and object extraction from digital imagery, in particular with regard to city modeling. This is already on the way, but certainly not yet finalized. It will require the fusion of digital image data and of lidar data. The software programs, whether completely automatic or to some degree interactive, will have to deal with very large sets of high resolution data.



- In the near future the further development and application of digital cameras will continue, also of small format cameras. Companies like Inpho will have to adapt their software to different classes of digital cameras. Also satellite imagery with higher resolution may come, perhaps with pixel terrain resolution of 0.5 m or less. The technology is available, but the time of realisation will depend on financing and market considerations. Higher resolution satellite imagery will not cause great new problems for the existing data processing systems.

- The above examples can be taken representative for the general expansion of digital sensor systems and of digital products. It implies in particular lidar data, combined with digital camera data, the latter perhaps extended into the near infrared range. The tendency is in general towards more integrated systems with the challenge for more versatile software systems to handle flexibly and effectively different applications.

- Inpho has not been active in the field of remote sensing, so far. It has always been focused on the geometric kernel performance of data and products. Whether this will have to be reconsidered remains to be seen, as thematic and geometric geo-data processing will have to converge.

The future development of company strategies and of the application and market situation in our discipline is more difficult to be assessed than the path of technology, at least in my opinion. The technical performance alone may have effects on the market scene and on the attitude of the user communities. In addition independent structural changes may happen, which might thoroughly affect the administrative frames of our fields or touch even the general esteem of geo-information in future societies. Such moves have been going on for some time and have already caused enough

disturbance. They will certainly continue to the extent that our previously enclosed and stable world of surveying and mapping will disappear completely in favor of more open interrelated structures. This is a certain difficulty, but also chance and challenge.

It is the development of Geographic information systems in the widest sense which will dominate the future development, in terms of contents and of effects. Their range goes and will go much beyond the traditional frame of our work. Photogrammetry is directly and mainly concerned with integrated data acquisition and data merging, and with its role in various user systems, whether these are planning systems, general administration, or engineering and monitoring systems. The general tendency towards GIS is clear, in my opinion, but it is too wide a field and split into various subsystems which makes it difficult to anticipate clearly which forms will dominantly emerge. Production companies may have to make decisions on different levels, as the range will extend from simple to most sophisticated systems, up to the level of governmental or national administrations. Perhaps also the user community will disintegrate by different demands.

Let me close these superficial considerations and come back to the case of Inpho company. It has so far maintained itself very well and solved the occasional difficulties. It is one of the very few major photogrammetric software companies in Europe which has maintained itself through the turbulent structural changes which have shaken up photogrammetric hardware and software industry, as well as the user communities and their demands. Inpho has certainly the intention to continue its path and to play its part in modern photogrammetry which expands into the vast world of geo-spatial information. We are aware that careful observation and anticipation of developments will be required in order to be able to react in time and stay prepared for the future.

I wish and hope that the development of the geo-data field will be intense and provide satisfaction and success to all who are concerned with it. And I may be allowed to wish also Inpho company that it will manage to remain an interesting and successful player in the field, to expand its operational platform, and to maintain a clear field of competence.