ISSUES IN MEDICAL PHOTOGRAMMETRY IN THE DIGITAL IMAGING ERA

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ABSTRACT:

Considerable effort is being applied by photogrammetrists to develop aids to medical measurement. But the photogrammetrists' effort is not being rewarded with *routine* usage in the medical world. This situation has become more complicated in the era of digital image processing, as measurement systems developed by non-photogrammetrists are finding commercial use. This report examines issues in photogrammetry's implementation in routine clinical measurement. It is concluded that there remain worthwhile applications of external bodily measurement in medical and health studies, and there are many applications for which realistic alternatives to photogrammetry have not been advanced. Some inconspicuous but useful areas of measurement, to which photogrammetrists have rarely paid attention and for which demand has not been recognised, deserve to be investigated. Many useful applications do not need sophisticated measurement. At the same time, medical photogrammetric developments which are not intended for commercial use should not be seen as unproductive. Photogrammetrists should note that, because digital photogrammetric methods involving targets can easily be adopted by non-photogrammetrists, photogrammetrists should concentrate on automated surface measurement through image matching.
Good communication with those working closely with medicine and health is crucial. Photogrammetrists have failed to communicate beyond their own ranks, and have continued to be under-represented at relevant bio-medical conferences. ISPRS Working Group V/5 may now need to concentrate its meetings on one area of the body, or one type of measurement technique. The Working Group needs to publicise photogrammetry's capabilities, and must continue to report relevant medical photogrammetry matters back to the ISPRS membership.

1. BACKGROUND

For at least a few decades, an extensive amount of useful development work has been carried out in medical photogrammetry. Photogrammetrists have been trying to apply their techniques and skills to the benefit of medicine, as photogrammetry offers a measuring tool capable of high precision and reliability. Papers discussing the use of photogrammetry for biomedical ends are abundant. There have been some successful implementations of photogrammetry for medical purposes, and there have been some commercial outcomes.

But readers will, on reflection, recognise that it is only a small percentage of the developments that appear to find routine usage, and very few medical or health institutions utilise photogrammetry for clinical or surgical purposes. The total impact of the medical photogrammetry developments on the world remains quite limited. Accordingly, there is a risk that the photogrammetric development work is being wasted. It is equally possible that some duplication of work by photogrammetrists may be occurring.

This paper reflects on the difficulties of photogrammetry's implementation in medical measurement, and especially in *routine* clinical measurement, to learn from successful and unsuccessful implementations, to enumerate opportunities and to outline challenges in photogrammetric measurement. The paper is concerned with promoting a wider implementation of photogrammetrists' expertise into medical measurement. More detail is provided in a companion report, (Mitchell & Leemann, 1996), which effectively constitutes a report of Working Group V/5 for the 1992-1996 period.

The situation outlined above is not new. A former co-chair of the relevant Working Group has previously commented, Newton (1980), that "*The present situation of medical photogrammetry appears as a highly contradictory one. Although almost every researcher in this field has recognised the immense capabilities and usefulness of*

photogrammetry, the technique has remained largely experimental and is still far from being introduced into routine medical procedures"

Since that time, the high level of automation of digital photogrammetry has offered a breakthrough in medical photogrammetry's acceptance. Photogrammetric techniques which were laborious using film can be made acceptably fast and cheap for a clinical situation with electro-optical imaging and digital image processing. So wider implementation of medical photogrammetry may have been expected. But in fact the overall problem seems to have worsened as non-photogrammetrists have become more successful than photogrammetrists have been, at introducing optical-based medical measurement.

It should be of concern to ISPRS participants that medical photogrammetry has not always been implemented by photogrammetrists, but has often been achieved by bio-engineers and medical scientists, usually employing digital imaging techniques. Indeed, only a very limited number of medical persons able to utilise photogrammetry have ever heard of the ISPRS. So, while the opportunities of medical photogrammetry have been broadened by the introduction of digital photogrammetry along with other imaging technologies, the techniques used by photogrammetrists are no longer exclusive to photogrammetry, but are familiar in computer vision, robotics and so on.

Information for this study has come from various sources, including the published literature in the form of conference proceedings, journals and manufacturers' brochures. As journal and conference proceedings rarely supply crucial opinions and comments on issues of relevance, this material has been extended by personal opinions, some submitted via a forum held at the ISPRS Commission V Inter-Congress Symposium, Melbourne, 1994, by personal communication, by personal observations, and by contributions to this report from Working Group members, from other ISPRS members and even some persons not associated with ISPRS. A brief survey has also been distributed to those on the Working Group mailing list, and to ISPRS Commission V reporters around the world, to all other ISPRS office-bearers, and also to a number of contacts outside ISPRS. The survey was limited in its extent, considering the world wide usage of medical measurement but it was an important source of opinions and information, and provided real evidence about the involvement of photogrammetrists in medical measurement. There were two versions of the survey, one aimed at those believed to have a photogrammetric background and the other directed at those presumed to have a medical background. (There may of course be some errors in these classifications).

2. SURVEY RESULTS

Fifty responses have been received from the Working Group survey, 32 from photogrammetrists' and 18 from the medical survey. It was not surprising that there were more responses from photogrammetrists than medical personnel, the latter not normally being involved with ISPRS.

Of the 32 photogrammetrists' replies, 29 had been involved in research and development in medical photogrammetry. It is notable, however, that many of the 29 had been involved on multiple projects. Of the same 29 responses, 16 remarked that their work had related to medical *research*, 15 to *treatment* of medical conditions, 12 for *diagnosis* of individual patients, eight to *mass screening* for disorders, some work covering multiple categories. Analogue techniques were used by a number but analytical photogrammetry appears generally to have been bypassed in favour of digital methodology, which indeed was quite popular.

Of the 29 "photogrammetrists" who registered some medical experience, 15 declared that their work had seen medical usage. For these purposes, there were four reports of the use of digital photogrammetry, three of analogue methodologies and analytical, nil. Significantly, the use of structured light and moiré measurement methods were mentioned in other replies. Of the valid medical uses, most related to the back; others related to teeth, motion, the face and positioning surgical items.

The 18 reports of the usage of measurement techniques by medical personnel provide a useful commentary on the usage of photogrammetry. Most significant were the unexpectedly high usage rates for measurements, many reporting daily use. Very few reported just occasional use. Prof. J.U. Baumann (Basel, Switzerland) commented that photogrammetry had brought excellent results in body surface measurement since 1972, and a measurement rate of five patients per week would be doubled if feasible. The rates seem to suggest that if photogrammetric technique can be introduced to the appropriate user, high usage can be anticipated. As with the photogrammetrists, most attention was directed at major body surfaces (face, chest, pelvis, neck, thigh) but users also referred to the feet (two), teeth (two), jaw and eye (two). References to the back were surprisingly limited in this group!

The replies referred to a range of measurement techniques, from measuring tapes to contemporary medical imaging techniques and included x-rays, a reflex instrument, force plates, and accelerometers. Reference was made to a number of commercial optical measuring products.

Very noticeably, in almost all cases the measurement work was carried out within the respondents own unit, rather than by an outside agency, such as a photogrammetric institution. User-friendliness for the medical personnel would seem to be a key requirement of photogrammetric developments.

Overall, the survey suggested that, despite a concern about limited recognition of medical photogrammetry, there are many keen users, who use it frequently.

More details of the questionnaire and responses are given in the companion report.

3. APPLICATIONS AREAS FOR MEDICAL MEASUREMENT

Photogrammetry has, over the years, been proposed as a viable measurement technique for a range of areas of the human body, from the eye to the entire trunk, using a full range of techniques, now expanded via digital processing and newer technologies in medical imaging. Evidence of the quantity of papers is provided in the lists of references in chapters on the subject in monographs: Newton (1980) refers to 68; Sheffer and Herron (1989) list 72. Many other relevant papers are to be found beyond the circle of photogrammetric publications. Medical photogrammetry is also encountered at various congresses with a medical affinity, especially the proceedings of the Biostereometrics meetings which have of course considerable photogrammetric content.

The following broad areas of application for medical photogrammetry have been identified, and are discussed more closely in the associated full report. The main points from that report are as follows.

i) There is a real demand for *motion analysis* but with many participants already and with complex image processing and data analysis needed, small photogrammetric groups may find it difficult to make inroads into this field.

ii) Extensive conference series on *back* surface measurement purposes imply a significant level of demand. However, a number of sophisticated commercial products already exist. In addition, photogrammetric back shape measurement can now be done by commercial software for general photogrammetry. Furthermore, alternative optical methods, many automated, are currently more popular than photogrammetry. Moiré methods are simple but appear to be favoured less than the various structured light techniques. The Working Group survey shows that while photogrammetrists were involved in back measurement, few of the medical responses reported an interest in back measurement. Although back surface measurement can be perceived as an field of fruitful photogrammetric research, it would from all the evidence that this would not seem to be so.

iii) The limited number and the expense of existing *facial* measurement systems suggests that there are opportunities for more development. However, demands for detail and specialised output make this work demanding - and probably not justified in general, unless stimulated by contact with a individual medical specialist.

iv) For measurement of many *body surfaces*, structured light techniques are currently more popular than photogrammetry.

v) Opportunities are to be found in *dental* research, with little competition from other techniques or from commercial organisations. Interesting challenges occur in this worthwhile work, in which the experienced photogrammetrists can be indispensable.

vi) Among all the applications, repetition does not appear to be common, and there is only a limited amount of wastage through re-development by photogrammetrists and by non-photogrammetrists.

4. DISCUSSION

There is of course no simple solution to the general unproductive state of routine medical photogrammetry. There are many issues which have not been raised in the discussion so far but which are frequently raised in discussions on the question, at the ISPRS Commission V Symposium in 1994 in particular, but more generally whenever medical photogrammetrists meet and communicate. The discussion below puts some of the arguments concerning the challenges of medical photogrammetry and offers some solutions which interested and concerned photogrammetrists in general and the Working Group in particular may contemplate.

Medical photogrammetry has always faced its own special problems, which derive especially from the involvement of living patients, but which also derive from involvement with practitioners from a distinctly different discipline. Live patients mean coping with movement, and their comfort, convenience and safety. The challenge of having to relate to and interact with other health professionals involved in a wide range of medical and health matters requires that photogrammetrists understand their wants and needs and supply medically important information in a useable form. But some specific issues relating to photogrammetry's implementation are as follows.

i) Although medical photogrammetry suffers from the difficulty that it measures externally rather than the internal circumstances which typically affect health and medicine, it must be recognised that a role exists for external measurement when internal measurement techniques have dangerous side-effects or high cost. All applications, whether for routine clinical measurement or for medical research, for recording high-speed human motion, deducing the shape of the spine from the back, recording all-round shapes of the torso, limbs, or feet, measuring the intricate detail of the face, measuring the cornea and the retina, and inside the mouth, are very beneficial and can make valuable contributions to the community. There may be rewards, even financial, to the photogrammetric community.

ii) Many medical photogrammetric developments are carried out by academic institutions and are intended for unique projects, and not for reproduction, yet alone commercial use. Such development should not be seen as unproductive, but rather as worthwhile areas in which commercially-driven organisations cannot be expected to contribute. Perhaps commercial success is not always pertinent, especially to photogrammetrists interested in making a useful contribution to medicine.

iii) There is evidence that there are many useful applications which do not need sophisticated measurement, but sometimes no more than a tape measure perhaps with clever analysis of its output. In this vein, it is notable that the one of the prime considerations in the highly valuable

probe positioning system (Adams *et al.*, 1994) is really the comparatively simple (if unfamiliar to medical practitioners) three-dimensional co-ordinate transformation. Indeed, in a survey reply, Osterwalder reported currently using "very simple almost primitive tools" including a measuring tape, in daily diagnosis and treatment, noting that equipment used in future would be more accurate and time saving - and not simply more impressive! We must be careful to bear in mind the end users' requirements.

iv) Photogrammetry faces most competition from measurement which can be carried out utilising targets while photogrammetric methods involving measurements on surfaces via a random network of points can more easily be undertaken by photogrammetrists, who therefore should consider concentrating on measurement involving the matching of corresponding points.

v) Although in many cases of real need in external medical measurement, realistic alternatives to photogrammetry have not been advanced, photogrammetry does face strong competition in certain applications from "non-photogrammetric" alternatives, usually optical techniques, which deserve some recognition and consideration, and the importance of the alternatives should be assessed.

vi) It must be accepted that medical practitioners are bombarded with other technologies, and photogrammetry is not always vital. Announcements for the new journal, *Biomedical Optics*, from SPIE, for example, describes the scope of the journal does not mention photogrammetry in a long list of its topics of coverage. It is argued that surface measurement must have qualities which allow it to compete with other attractive technologies.

Communication. The above points do not fully explain any failure of photogrammetry to be more widely used. Frequently, the discussion on this matter relates to the problems caused by the need to communicate with the medical profession. It is of course crucial to understand exactly what the medical practitioner wants, to understand exactly what the requirements and demand are for medical measurement. Photogrammetrists pursuing medical measurement need to recognise the full requirements of the medical practitioner. These requirements may relate to accuracy or cost or convenience or other matters. Photogrammetrists need also to ensure that the medical worker understand clearly the capabilities and limitations to photogrammetry. Especially important is the need to provide meaningful medical parameters or other information which is easily interpretable, and making the effort needed to find acceptable means of supplying useable information. Poor communication with the medical profession can obviously lead to wasted work in which the exact and complete requirements of the end-user are not clear.

It is also arguable that better communication can pinpoint demand and opportunities which are otherwise not foreseeable, but which can be uncovered by contact with those in another profession. It can lead to missed opportunities, such as in real-time monitoring of surgery (see Tredwell *et al.*, 1995), or perhaps even in the lucrative area of assisting sports training.

Photogrammetrists need the direct help of the medical profession. The Working Group needs not only the contact, but also the acceptance of the medical profession. There remain some less obvious but useful areas of measurement which have not been tackled by photogrammetrists, but which deserve to be investigated, and which may be discovered by contact with medical practitioners.

Communication should not only be directly with the medical profession but also with bio-medical engineers and other technologists who are often more closely involved with measurement and whose education and scientific/engineering background makes communication less complicated.

In some ways, photogrammetrists have made themselves remote. Adams (1994, personal communication) warns that, "*We have the unhappy knack of making our discipline sound so complicated and intricate that we scare off our customers who then go and re-invent 'our' wheel.*"

Photogrammetrists need to be clear about their own skills. The skill of the photogrammetrist has essentially meant an ability to deal with three-dimensions and with precision and accuracy.

Overall, the current communication must be improved. To date photogrammetrists have been under-represented at relevant bio-medical conferences. Trinder (J.C. Trinder, University of New South Wales, personal communication, 1994) has reported that the meeting on scoliosis in Toronto in 1992 "*did not include too many photogrammetrists*". The report on the last International Symposium on Three Dimensional Scoliotic Deformities combined with International Symposium on Surface Topography and Spinal Deformity", held in 1994 in Pescara, Italy, noted that, "*Attendance appeared to derive largely from the medical profession, but with a significant number who could be categorised as bio-mechanical engineers or scientists. Very few would have classed themselves as photogrammetrists*", (Mitchell, 1995).

Whether these outcomes are due to a lack of desire on the part of photogrammetrists to attend or whether it is due to ignorance of the existence of the meetings is impossible to be certain about. However, it seems reasonable to conclude that photogrammetrists interested in measurement should know of these conferences and attend. The Working Group should publicise the existence of such meetings.

However, we must be careful about the meetings. One concept that appears to be prevalent is that to hold

meetings on general medical photogrammetry is not reasonable, as we get technically so diverse. Perhaps the Working Group should try to concentrate its efforts, or its meetings, on a certain topic area - and possibly in conjunction with a medical group in that area. We need to work and communicate with the medical specialists, not the photogrammetrists, in a chosen specialised areas, such as spinal deformity. While Turner-Smith (Dr. A.R. Turner-Smith, King's College London, personal communication, 1994) has warned that, "*there is a tendency for potent areas of medical photogrammetry to form their own, clinically based meetings (back surface and spine shape, motion analysis - particularly gait analysis)....*", Herron (1990), in an introduction to the proceedings of the most recent (and so far the last) meeting in the biostereometrics series, pointed out that, "*The goal of this meeting was to bring together various exponents of biostereometrics technology and applications for the purpose of presenting and discussing information about recent developments. However, such is the diversity of the subject to-day that it is no longer possible to embrace all aspects in one short meeting. ...*". It seems overall that we should hold meetings on one area of the body, or one type of measurement technique.

The success of the non-photogrammetrists is perhaps due to their association with biomedical engineers in commercial organisations.

Grün (Prof. A. Grün, ETH-Zurich, personal communication, 1994) has pointed out that the Working Group must communicate relevant medical photogrammetry matters to interested ISPRS members. This, along with Grün's comment that the Working Group membership has significant expertise and should remain the principal medical photogrammetry society, means that the Group must be active in its involvement in ISPRS and Commission V activities and in its own communications.

Looking beyond medical measurement, it is apparent that non-photogrammetrists are heavily involved in developments of industrial measuring methods, and that few architects have used architectural photogrammetry. It may be reassuring to realise that many problems faced by medical photogrammetry are faced in other spheres of photogrammetry, especially in close-range photogrammetry.

5. CONCLUSIONS AND RECOMMENDATIONS

The evidence about the use of medical photogrammetry is sometimes contradictory, and as with most discussion, there ae often two sides to each argument. However, some conclusions should be drawn and recommendations should be made. The general conclusion is that there are numerous worthwhile, beneficial and rewarding applications of external bodily measurement for patient diagnosis, treatment and monitoring in medical and health studies.

Even so, it is true that medical digital photogrammetry has a level of ineffectuality considering the effort applied, and photogrammetry is not widely encountered in the world's medical institutions. Photogrammetrists need to be certain that their development work will ultimately see real use.

But, there are many applications for which digital photogrammetry has few realistic alternatives. There are also certain medical measurement tasks (notably motion analysis) for which demand is high.

The measuring techniques need to be suited to use close to the interested medical practitioner, not in a remote laboratory. Once the measurement methods have been developed, usage rates are high.

For more widespread acceptance of photogrammetric procedures, automation through the use of digital techniques is often crucial. However, progress in digital technology has meant that photogrammetric developments have now been carried out by both photogrammetrists and by non-photogrammetrists.

There are those in the photogrammetric or medical professions who have been successful at implementing and/or employing photogrammetric techniques. The productive areas of medical photogrammetry so far lie in gait and scoliosis studies, but in these fields there have been commercial developments which deserve to be identified. The photogrammetric development needed for successful implementation - commercial or otherwise - is extensive and has only been successfully carried out by commercial organisations or by research groups of significant size.

Photogrammetrists should consider concentrating on measurement involving the matching of corresponding points and must equally recognise the advantages of alternatives to photogrammetry and consider their use.

Other optical techniques are useful and viable, and they deserve some recognition and serious consideration.

Although the Working Group has been a successful and productive component of Commission V, the opening up of photogrammetry to non-photogrammetrists in the digital era, demands that it assists photogrammetrists by helping open channels of communication to the broader medical community. This may be achieved by encouraging attendance at bio-medical conferences and by submitting papers to bio-medical journals, and by contact with bio-medical engineers or other groups experienced in the problems and the demands of development of medical instrumentation. The Working Group should concentrate on providing and utilising networks which foster such interaction with willing bio-medical professionals.

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