Meeting Reports

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Feedback Control of Exposure Geometry in Dental Radiography Workshop, University of Connecticut, 16 May 1978

Reported by Richard Gordon, University of Manitoba

Stereotactic methods are used in surgery when the precise location of damaged or pathological tissue is known in three dimensions. For example, 3-D information is obtained by holding the patient's head in a rig, using rods stuck in the ears, while taking x-ray pictures. In feedback-controlled stereotactic radiology a computer-controlled x-ray apparatus can compensate for changes in the orientation of the patient. Feedback control in radiography thus achieves stereotactic imaging without bolting the patient to the apparatus. If instruments with such capabilities were built, stereotactic imaging could become a more acceptable and more widely used diagnostic method.

Beyond facilitating precise surgery, stereotactic imaging allows one to follow the time course of a disease or the motions of an organ in a quantitative fashion. Furthermore, diagnosis can be improved via quantitative image processing which takes advantage of the time sequence. The x-ray dose to the patient can also be greatly reduced. One can even conceive of stereotactic surgery or dentistry carried out under direct computer control.

This workshop was convened in May last year at the University of Connecticut School of Dental Medicine to explore the possibility of using feedback control to improve dental radiography, before any apparatus are actually built. It was organized by Richard Webber of the National Institute of Dental Research (National Institutes of Health, Bethesda, Maryland) on behalf of the Technology and Equipment Committee of the American Academy of Dental Radiology.

A number of **dose reduction** schemes were suggested during the workshop. If one can aim an x-ray beam, one can avoid tissues such as bone marrow, which has proliferating cells. Such tissues have a higher probability of becoming cancerous from radiation damage (**Allen B. Reiskin**, University of Connecticut). One can also avoid dental fillings, which over their area of the image contribute nothing to a diagnosis, since they are nearly x-ray opaque. A more refined version of such an approach uses a higher dose for better imagery only in those areas suspected of containing caries or periodontal disease (**Roger Nagel**, NIDR). Most of these methods are object dependent, require the use of *a priori* information, and thus involve highly nonlinear computational algorithms.

Under computer control the x-ray beam may be confined to a volume that strictly intersects the detector, so that no radiation is wasted (**Richard Webber**, NIDR). A simple computer search algorithm could allow an intraoral detector to be precisely located in the mouth. If a detector array is used, the primary beam may be distinguished from scattered radiation. A multilayered detector can perform a rough energy discrimination.

An aimed beam allows one to attain a uniform signal-to-noise ratio by holding the beam at each point for an appropriate length of time. If the peak of the x-ray spectrum could also be dynamically tuned to the optimum energy for each local optical thickness, further dose reduction could be achieved.

There are two roles for **image processing** in stereotactic radiology in dentistry. The first is as an aid in the acquisition of an image. The second permits one to follow the time course of a disease.

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Caries on surfaces between teeth are often obscured by overlapping of the images of the teeth. The plane separating adjacent teeth could be located by obtaining a number of views from different angles to find the one with maximum peak transmittance. This could be done at a very low dose. Then a standard image could be taken at this optimal orientation. The beam could also be aimed selectively at crown, roots, gingiva, or other tissues of interest, if appropriate pattern recognition algorithms were written.

Webber emphasized the importance of standard views so that the progress of periodontal disease could be followed from one dental visit to another. He showed numerous examples of ordinary dental x rays of the same teeth taken at slightly different angles at the same sitting. Dentists could easily interpret one image of a tooth as indicating extraction while another of the same tooth as normal (false negative diagnosis). Thus relatively large lesions often escape detection. (False positives are also possible.) Standard views could be reproduced from session to session by using appropriate pattern recognition algorithms. Thus adequate and timely treatment of patients would be insured.

The second use of image processing in dental radiology, given this ability to repeatedly view a tooth from the same direction, is to compare the tooth at different times. The registered images could be subtracted, and so forth, and a wide variety of image enhancement methods applied. It is even plausible to compare the two images *during* data collection, so that a difference-image is acquired at considerably lower dose than the original. If the patient's digital image records were preserved, she or he could be subject to such incremental radiology from then on.

The workshop was called in anticipation of **advances in technology** making aimed-beam radiology a practical reality. An important precedent for medical radiology was set by the workshop: ideas and algorithms should be worked out prior to their embodiment in expensive instruments. In contrast, this did not happen in the closely related field of computed tomography, which is now saddled with numerous Rube Goldbergs of limited capabilities.

The first aimed-beam system was designed by R. J. Moon [(Science **112,** 389 (1950)]. It consisted of an x-ray tube with a large anode over which an electron beam was steered. The x rays were collimated by a single pinhole on the face of the tube. This design, which utilized only a tiny fraction of the x-ray photons generated, has been reincarnated into a modern computed tomographic apparatus [Y. Tateno and H. Tanaka, *Radiology* **121,** 189 (1976)].

In a newer design **Richard D. Albert** (X-Ray Systems, Danville, California) scans an electron beam over the face of a tube from which x-ray emission occurs (U.S. Patent 3,949,229). His very first radiographs, presented at the workshop, show considerable promise. However, it became apparent that, to protect the patient from unused radiation, considerable thought would have to be given to the design of collimators. But heavy lead collimators interfere with or limit dynamic aiming of the beam, especially since they cannot be changed or moved rapidly. Thus various speculative alternatives were brought up, such as lead disks or collimators spinning in front of Albert's tube, reminiscent of early television, or sheets of liquid crystal lead compounds in which electric fields could create transient pinholes. Whatever the most feasible mechanism, the workshop participants identified a clear need for a programmable x-ray collimator. The alternative is a steerable x-ray laser beam. Steering might be accomplished at visual or ultraviolet wavelengths prior to frequency multiplying.

Feedback control of radiological imaging may come to have a major impact on diagnostic dentistry and medicine as a whole. This workshop has laid the foundation for careful development of the necessary technology.