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A Model of Expert Inspection of SPECT Heart Images

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Single photon emission computed tomography (SPECT) provides a non-invasive means of diagnosing coronary artery disease by representing the perfusion of the myocardium in graphical form. Clinicians view sets of tomographic images presented in three different projections through a number of filters, which change the granularity of the image data. Perfusion imaging provides a rich, though imperfect, source of data on heart function; the images are subject to artifacts. The InSPECTA expert system, currently under development, assists nuclear physicians in the interpretation of SPECT-generated perfusion images of the heart (Turner & Andrews, 1997). A rule-base encodes expert knowledge of perfusion imaging, heart physiology and anatomy, and coronary artery disease. The diagnostic system's primary task is to infer the presence of genuine perfusion defects in a patient's heart from the apparent defects on the images. The system also makes use of data from sources other than perfusion imaging, including patient history and first pass functional imaging. InSPECTA also includes a graphical explanation system which is based on the hypermedia system found in NUCES, the Nuclear Cardiology Expert System, a knowledge-based system for diagnosing heart disease from first pass functional images (Ford et al., 1996).

During the knowledge engineering phase of design, concept maps provided a high-level overview of the domain of nuclear cardiology and perfusion imaging; protocol analysis of patient diagnoses yielded details of expert performance during diagnosis. Analysis suggested two levels of visual categorization. At the first level, individual images are examined for the presence or absence of defects. If found, a defect is broadly assigned by location to one of three categories (small, medium, or large). At the second level of categorization, patterns of defects across all of the relevant images are perceptually grouped into one or more defects by location and size (mild, moderate, severe). Hypotheses are formed as the clinician observes the pattern and quality of defects in the images; inspection order of the images is partially driven by the hypothesis under consideration. Explicit rules about functional change between stress testing and rest testing are applied to data from the images and weighed for predictive value with other data (EKG, first pass, patient history). Domain specific knowledge—of artifacts, anatomical variation between patients, the likelihood of genuine defects in different areas of the left ventricle—can cause initial hypotheses to be confirmed or changed. The final diagnosis may include ischemia, myocardial infarction, and the cardiomyopathies.

Findings were consistent with earlier work on expertise: the expert groups images in a single judgment, checks for confirmation, and tends to ignore irrelevant data. Initial testing of the system found a reasonable fit with the domain expert's order of inspection and the system's model of inspection, although the diagnostic system lagged well behind the performance of the expert. An assumption was made that data entry should begin with second level categorization and follow relevant hypothesis. However, testing with novice readers exposed qualitative differences between experts and novices during an examination. Novices' categorization of individual images were consistent with the domain expert's, but their perceptual groupings of images were inconsistent and more varied than judgments supplied by the expert.

A simple approach to data entry would have solved the grouping problem by forcing users to input ratings of the size and severity of each defect as it appears on every (over 100) image, plus the functional change between each exercise/rest pair of images, and allow the system to furnish the perceptual groupings. Instead, InSPECTA was developed with an adaptive interface that accommodates the relative expertise of its user. During a consultation with InSPECTA, the order and type of questions presented to the user are based on an interaction between four factors, including (a) expert knowledge of the domain, (b) the hierarchy of specificity of questions, (c), requirements for confident diagnosis, and (d) user preference for data input.

References

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