Categorical Data, and a Physicians Bayesian-Like Thinking Process: Relevance to PS-OCT

Summary

For over a decade, we have tailored our PS-OCT to address clinical need, not the question for more precise numerical data. Engineering and medical approaches are the right one's for their respective fields, as long histories have demonstrated. Engineering generally is based on precision numerical data. For medicine, categorical data with high sensitivity and specificity to be integrated into a Bayesian-like thought process is the how the field operates.

General

PS-OCT has two general embodiments, the single and dual channel approaches. Our group strongly favors the former, which we believe has the highest potential clinical impact and our clinical work bears this out. But the same conclusions can be drawn without looking at our over ten years of experience in this area. Proponents of dual channel support the technology under the context it produces precise numerical data (essentially continuous), which they deem superior to categorical (either nominal or ordinal data). We question not only whether precise numerical data is produced (separate section), but also whether clinical needs in the vast majority of cases dictate categorical data over precise numerical data. With respect to the latter point, medicine uses categorical data, particularly imaging data, a point largely ignored by proponents of dual channel approach (though precision is strived for instrumentation construction). Physician then use the categorical data in a Bayesian like process to adjust percentages for likelihood of diagnosis as data (within broad categorical ranges) comes in. A patient comes in with fatigue and the physician begins assigning probabilities to different etiologies. The percentages get adjusted with incoming data. The chest x-ray shows enlarged lymph nodes behind the heart (categorical), low grade fever (again categorical, could be 100.5 or 101), elevate SED rate (could be 15 or 40), anemia (HCT could be 30 or 39) and elevated blasts (could be 1% or 20%). The patient has leukemia that can be confirmed by examining the blood and bone marrow under a microscope. Notice that data to three significant digits is not needed and the range (mainly normal versus abnormal) is very wide. Sensitivity and specificity are established from categorical data (mild, moderate, etc) and not extending precision numerical results (this holds even in clinical trials and not just in the patient care setting). Each piece of data (which general has a broad categorical range) is being used to alter the percent likelihood of a pathology. Single channel PS-OCT gives rapid, reliable, and categorical data that is easy for the physician to interpret (and integrate with other categorical data). This is why we have been able to use it successfully, with surgeons, in vivo.

The Data Used Clinically (analogy)

So experts in the medical and physical science, as stated, often approach the problem from different directions, causing some mutual miscommunications. For those who have not routinely practiced medicine, it is hard to illustrate why categorical data is preferred just as to the clinician, the emphasis on numerical data would be somewhat foreign. By citing central medical texts (below), we provide below an unbiased resource to confirm statements above. But an analogy, atypical because it is non medical, is provided to illustrate the situation physicians typically find themselves in. Suppose that 1000 feet away in an open field was a tiger. The question of major concern is whether the tiger is

moving toward the observer, stationary, or moving away, but in the context of other conditions (terrain to run in, is a car near by, etc. which alter the Bayesian-like thinking process). It would also be useful to know if it was moving, whether it was walking or running. The observer has two devices, a pair of binoculars and an optically based velocity meter, both assumed constructed to high precision. But to answer the question needed, pulling the binoculars out of bag, getting a quick answer (general running versus walking, as well as direction, can be readily easily assessed by relative movement of limbs and with respect to the ground) is the optimum strategy to decide if the observer needs to run (along with the rest of the data they use in the Bayesian like process). However, the observer may decide on the velocity meter, wanting to know with high precision how fast the tiger is moving (too let's say three significant digits). Some embodiments of this technology involve considerably more effort and time. Anyone who has used in sports even a high quality velocity or distance meter is aware that accurate alignment can be relatively slow and frequently leads to gross aberrant reads. With respect to the latter point, data can be dramatically influenced by many sources of error including environmental factors or even not measuring right on the tiger (getting a velocity of zero). Errors of this type in making the rapid decisions are highly unlikely with the binoculars, which gives less precise data (actually categorical).

Hopefully this crude example serves as an analogy to the clinical imaging rationale. Now some would argue that through considerable engineering both speed and artifacts are not an issue with dual channel PS-OCT. But the question has to be asked what data over that given by the binoculars was either worth the sophisticated engineering or the potential of an artifact reading that leads to a completely opposite answer. Clinically, when measuring glucose, it is generally better to get a quick reading where you know it is between 95 and 110, then a reading of 100.55 with a higher chance of artifact. Nothing is gained by the higher precision. Extending this to the PS-OCT argument, even if embodiments are dual channel are produced that are fast and have low artifacts, what clinically relevant information are being produced to justify the complexity, cost, and potential artifacts. This is the clinical reasoning. Assume an internist is approached by someone who developed a technology which they said would replace a chest x-ray for tumor screening by measuring exact scattering of tumor and non tumor tissue. They have made it high speed and are confident it compensates for most artifacts such as overlying tissue, varying tissue composition, movement, etc. If the internist were asked if they would use it, it would assume the answer would be no unless some overwhelming clinical benefit existed which justified the risk of artifacts. So I am always amazed that the question never seems to be asked, what additional clinical benefit does dual channel have that justifies the effort to increase it's acquisition rate and reduce artifacts, as well as accept additional costs.

Imaging and Categorical Data

Our group has been involved in the both the technological advances of OCT as well as it's application for over 17 years. Developing OCT technology (as opposed to application), and imaging technology in general, requires precision technology development. If one looks at an example text, "The Introduction to Medical Imaging: Physics, Engineering, and Clinical Application", the fact that engineering and clinical application sections are approaching problems from a distinct analysis is readily apparent and consistent with our direction for moving forward the technology. In this textbook,

the physics and engineering of conventional radiography, CT, MRI, and ultrasound are examined in considerable detail and individually. For all the modalities, from an engineering prospective, the book examines maximizing the technical performance in term of the point spread function, signal to noise ratio, dynamic range, contrast, etc. (precise numerical data). However, for all the clinical application sections, diagnostic analysis is categorical with extremely few exceptions. In the vast majority of cases, clinicians evaluate images based on visual recognition of a contrast difference, not based on numerical data. A mass on a chest x-ray, the ultrasound identification of a alcoholic liver, the MRI diagnosis of cartilage edema, or a bone infection by CT are all based on the visual identification of altered contrast, with no numerical assessments (discrete or continuous) involved. And again, we are exploring the basis for superiority claims of dual channel PS-OCT; that its presumed precise numerical data is superior for clinical use compared to the relative or categorical data of the single channel approach.
But if one takes an introductory text like, "The Right Imaging Study, a Guide for Physicians", numerical data is not apparent in any section of the book. And even when numerical data is potentially available as can be seen, it still is typically presented/examined as ordinal data (absent, mild, moderate, or severe). Common examples include most flow measurements (ultrasound, MRI, or coronary angiography), edema (bone MRI), cartilage breakdown (MRI), and pancreatitis grades (scale 1-5), all of which the available numerical data is presented categorically. It would probably be a surprise to many in the OCT field that even elastography (ultrasound and MRI) and anisotropy for collagen (MRI) are represented by categorical data though numerical data is available. Both OCT elastography and PS-OCT are usually presented in publication s by OCT groups as numerical data, including at times our own. But this is engineering convention, not how it would be used clinically.

The clinical acceptance of an imaging modality (and most diagnostic technologies) is based on its ability to effect morbidity or mortality, which typically does not correspond to it's ability to produce precise numerical data (discrete or continuous). This is the impact of the technology on medicine, not it's precision. Instead of numerical data, most clinical analysis with imaging modalities use categorical information, either nominal or ordinal data, which can be assessed rapidly. When clinical trials are performed, the categorical data comparisons are usually compared in terms of specificity and sensitivity, which clinical scientists are most interested in.

Conclusion

So again, for over a decade, we have tailored our PS-OCT to address clinical need, not the question for more precise numerical data. For analytical chemistry or measuirng low level background radiation in space, precision is essential. Engineering and medical approaches are the right one’s for their respective fields, as long histories have demonstrated. A fact the PI, beginning both an engineer and practicing physician for decades, can attest to. Engineering generally is based on precision numerical data. For medicine, categorical data with high sensitivity and specificity to be integrated into a Bayesian-like thought process is the how the field operates. This, along with technical advantages, is why we strongly prefer single channel PS-OCT over dual channel.