Reasoning about ultrasound with diagrams

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I am researching the use of imagery to reason about the motion of objects - at present, the motion of ultrasound pulses. With Paul O'Rorke at UCI, and in collaboration with Douglas Aircraft Company, we have investigated the automation of crack detection in metal aircraft parts using ultrasound. We have initially concentrated on the diagnosis of known faults in a set of standard test blocks, one of which is shown in cross-section in Figure 1. A transducer containing a piezoelectric crystal generates a sound pulse which travels through the metal block and reflects off surfaces. The crystal is also used to detect any reflections that travel back to it. Figure 2 shows an ultrasound reading derived from the transducer readout. It has three peaks due to reflections from the front, 'crack,' and back surfaces of the block. (The large front wall peak is truncated at *Amplitude* = 30.)

We are developing a system that diagnoses the presence of a crack in a block by comparing an expected, two-peak reading to the actual three-peak reading, and explaining the third peak as being caused by sound reflecting off a crack within the block. The comparison of expected and actual readings is done using symbolic, feature-based descriptions of the readings. We use an efficient algorithm to extract features from the actual readings (Morris, 1992). The expected features are generated by assuming an uncracked block and inferring the motion of the test pulse to see what resulting reflections return to the transducer.

The overall diagnostic process is controlled by a symbolic reasoner *SR*. *SR* reasons about sound motion using simple theorems of geometry and the physics of ultrasound. To support this inferencing, *SR* calls upon an imagistic reasoner *IR* to simulate selected portions of the motion. *IR* uses an occupancy array representation of the spatial structure of the block and the pulses. *IR* reports to *SR* trajectory lengths, points of contact, surface and region identities, angles of incidence, extents of collision, etc. *SR* uses this information to infer the generation of reflected and transmitted sound pulses, whether they hit the transducer and when.

Some collisions can be modeled simply. If a pulse encounters a large flat surface beyond which is a region of gas (e.g., the back wall), the pulse can be modeled as a single point undergoing an elastic collision with the surface. Other collisions are more complex, such as a sound pulse encountering a small crack. A part of the pulse is reflected, while other parts go around and past the crack. One way to model this case is to conceptualize the pulse as an ensemble of particles and simulate the motion of a few representative particles. Here *SR* uses initial extent-of-collision information from *IR* to decide on this more detailed, ensemble representation. *IR*'s ability to detect such a partial collision is an example of the need to use relatively fine-grained metric information rather than a purely qualitative approach to space and motion (Forbus, Nielsen, & Faltings, 1987).

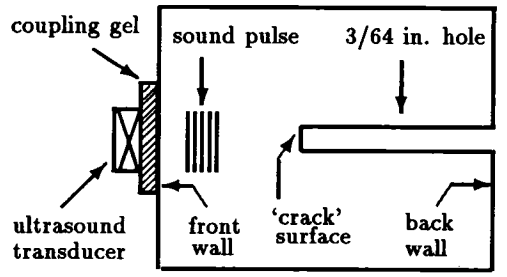

Figure 1: Test block and ultrasound test setup.

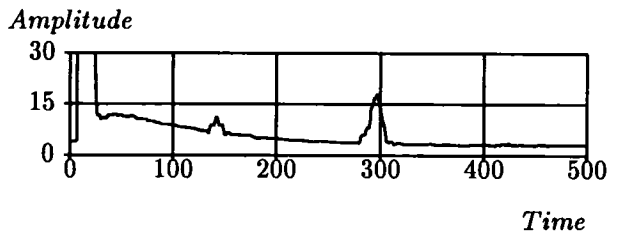

Figure 2: Ultrasound reading of test block.

Our initial research is more fully described in (Morris & O'Rorke, 1991). Future research will explore (1) the efficacy of using analogue representation for motion reasoning, (2) the interplay between symbolic and imagistic reasoning and the associated knowledge representations, and (3) control and use of models of varying levels of detail.

References

Forbus, K. D., Nielsen, P., & Faltings, B. (1987). Qualitative kinematics: A framework. In *Proceedings of the Tenth IJCAI.*

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