TWO-DIMENSIONAL DIGITAL COMPUTERS

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This talk is a report on OAST-supported work on advanced methods of data handling. We are developing data processing systems that will extract data from optical images. These will be simple systems, orders of magnitude faster than present computers. Earth resource imagery is an example of the type of images we have in mind. Our aim is to take a job that, using conventional computers, takes, say, 20 minutes; and do the identical job in 20 milliseconds or so.

Well, how? How can we actually talk about coming up with speeds that are five orders of magnitude greater than the computers we have now? Is it by coming up with faster components? The answer is no, that is not the idea.

What we want to do is build digital computers that operate on entire binary images instead of on individual binary bits.

We are talking about computers that perform not one logical operation at a time, but many thousands of logical operations simultaneously. It is this simultaneity that provides the increase in speed. We are talking about two-dimensional extensions of standard digital computers. We are talking about computers that don't involve any scanning. We are talking about computers that don't involve any point-by-point operations.

The first thing we have to do is to build logical components that, instead of operating on a point-by-point basis, operate over entire images. For instance, if you have an image *A* and an image *B* (Figure 1), the idea is to have one component that will take these two as an input and give a logical output. Such an output can be the "AND" of the two images, the "OR" of the two images, or the negation of an image.

Say that image *A* consists of a million points. A standard computer would scan the image and take the negatives of all million points, one at a time, to produce the negative image on the right of Figure 1. You can, of course, take an image like *A* to the local drugstore and 24 hours later you have the negative of the image, and no million operations have been performed. What we want to do is to come up with very fast, real-time pieces of photographic film that will do all the operations shown in Figure 1. If we have "ANDs," "ORs," and negation elements, we have the elements to build a digital computer.

Figure 2 shows our first attempt at putting together a very primitive two-dimensional logical circuit. The input to the system is a scene that has points with neighbors and isolated points. The output will show only the isolated points. You might think of

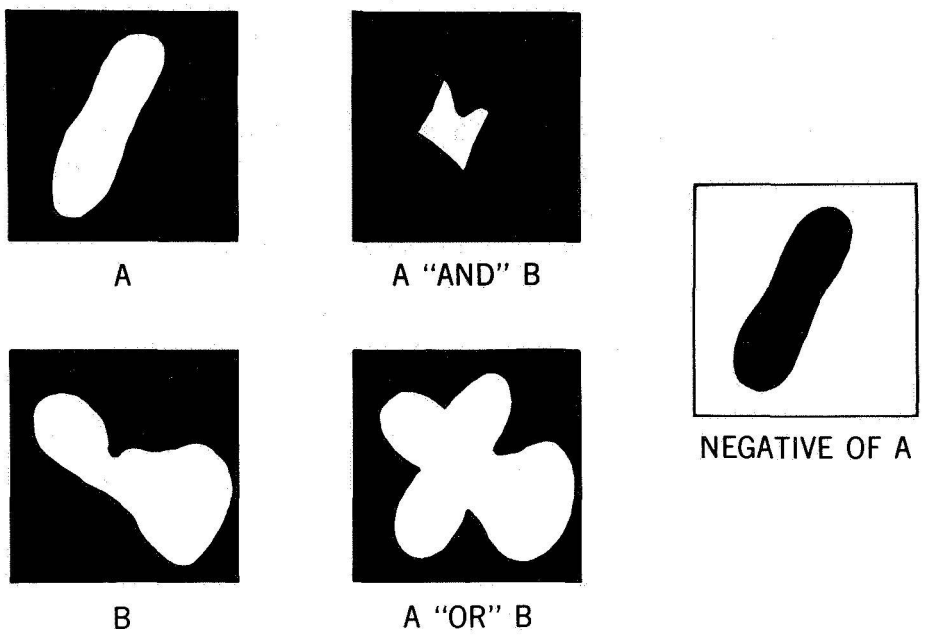

Figure 1. Two-dimensional binary logic.

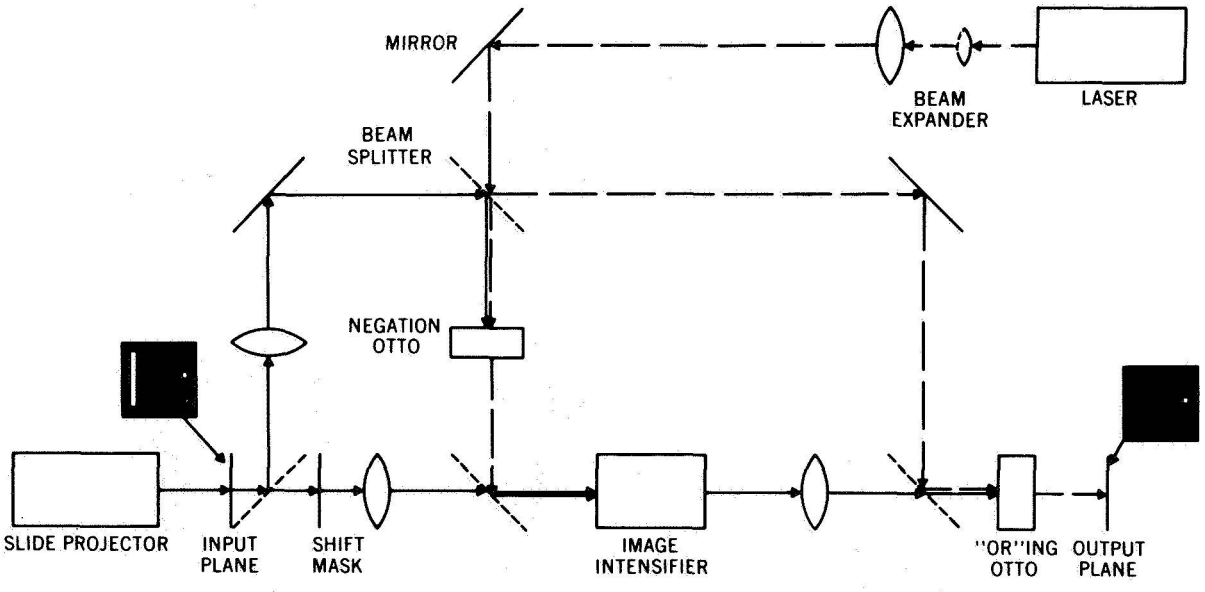

Figure 2. Isolated point detection system.

this as equivalent to an iceberg that has small pieces dropping off it. Perhaps the things you really worry about are these pieces. You would like a new picture that just shows the pieces that have dropped off, because you want to track those pieces, or you want to count them.

In Figure 2 are standard things of optics. There are lenses and there are mirrors. The unique thing is two elements: the negation element, and an "OR"ing element. These are liquid crystal devices that we have had developed for us. The negation element performs 20,000 negations simultaneously. In the area with the "OR," we do 20,000 "OR" operations simultaneously.

Figure 3 shows our very early results using the system shown in Figure 2. The upper images are inputs; the bottom images are outputs.

In summary, during the past year we have been able to build very primitive, two-dimensional, binary data processors. Using the concepts that we have demonstrated, we envision two-dimension general purpose computers. We feel that as two-dimensional computers develop, they will not only provide a method of handling images (both onboard spacecraft and on the ground); but that these computers will also have many uses not involving images. We are on the path to systems that have the potential to outclass conventional computers by four or five orders of magnitude, judged either by speed or by the complexity of the problems they can solve.

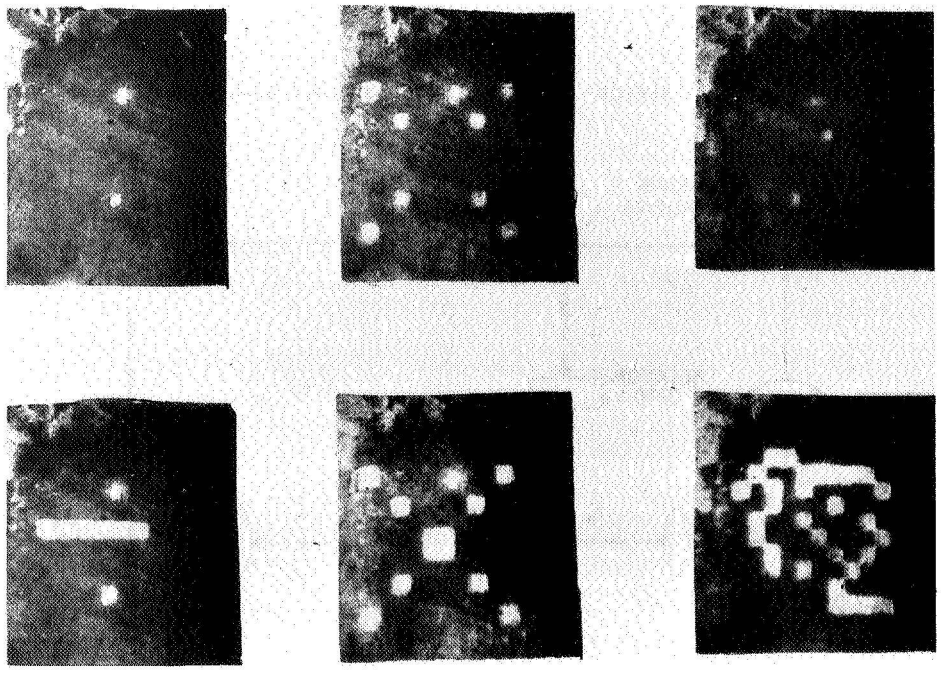

Figure 3. Experimental results using system shown in Figure 2.