Real-time image processing strategies for a retinal prosthesis

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Retinitis pigmentosa (RP) is an incurable disease that slowly destroys the sense of vision by attacking the light sensitive rod and cone cells in the retina. Short-term tests in blind human subjects with RP have shown that localized electrical stimulation of the retina with intraocular stimulating electrodes can allow these totally blind patients to see letters and simple geometric shapes such as a box. Based on these results, the National Science Foundation, the National Institutes of Health, and other organizations have funded projects dedicated to the engineering and testing of an implantable retinal prosthesis. The current prototype consists of an external camera to acquire an image and external electronics to process the image and transmit the signal to an implanted electronic chip on the retinal surface. The implanted chip will electrically stimulate the retina in a pattern appropriate for the image. This prototype can be built with existing technology. A conceptual drawing is shown below (fig. 1).

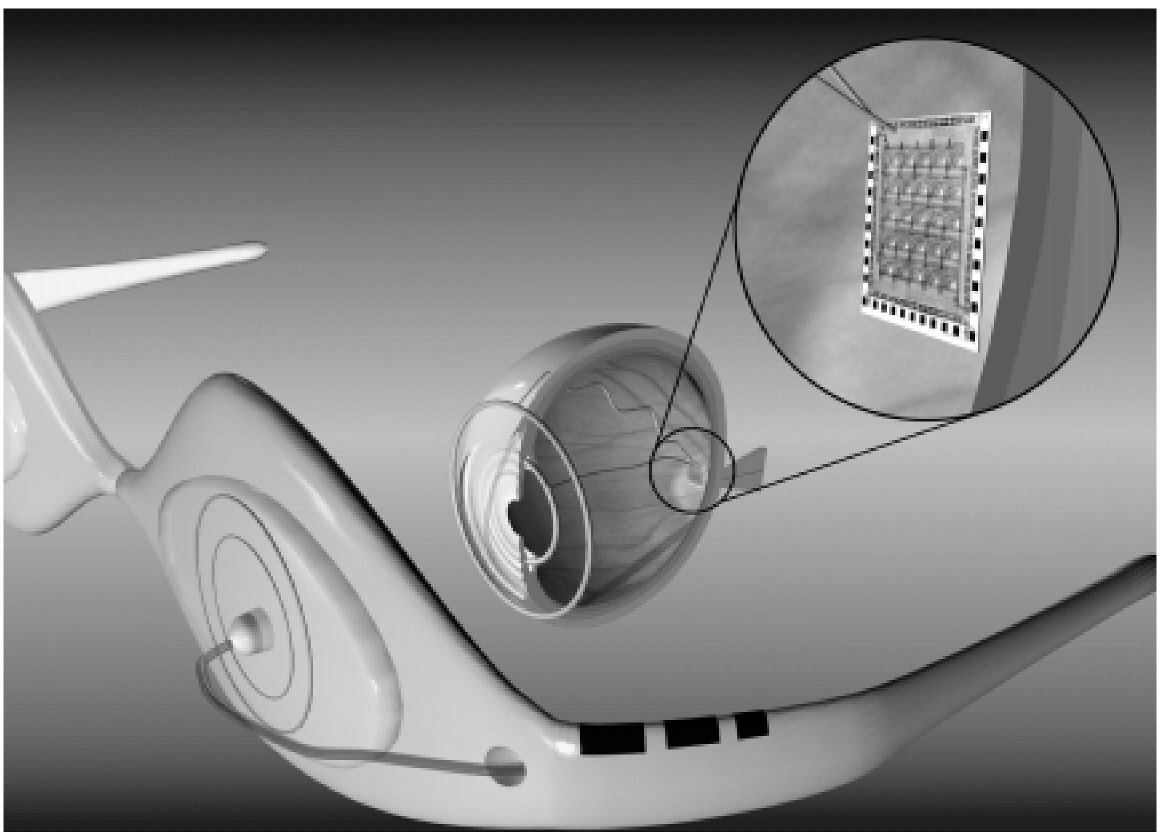

Fig. 1 – Conceptual drawing of retinal prosthesis.

Ideally, an implanted chip would replace photoreceptors (the light sensing cells of the retina) on a 1-to-1 basis to provide near normal vision. In reality, it would be impossible to replace all 100 million photoreceptors due to limitations in microfabrication technology, imaging technology and electrical packaging technology. The last area, electrical packaging, will most likely be the limiting factor in the number of “pixels” that will be available. Packaging for implantation is difficult since the device must make contact via metal electrodes to the retina, but must otherwise be hermetically sealed against the saline intraocular environment. Current methods will only permit 16 electrodes to be used to stimulate the retina, however, we estimate that we can extend this technology to 100 electrodes. Still, visual input will be reduced from 100 rather than 100 million input channels. Clearly, the implementation of an implantable retinal prosthesis must include video processing at some level.

Our current implementation of the video processing system uses an FPGA based device, but the power consumption of this system is prohibitive. DSP technology will be investigated as a platform for image processing at several levels. The initial prototype implant will most likely have fewer than 100 electrodes or pixels. Therefore, an image processor must condense a camera sensor array (480x640) into a 10x10 retinal stimulating electrode grid either through decimation or averaging. More advanced algorithms simulating retinal function (edge detection, motion detection) will also be developed. Future implants will have over 1000 electrodes on the retinal surface, a number that may place constraints on the amount of processing available in real-time. Power consumption is an important design consideration whether the image processor is external or implanted. An implanted system would benefit from a high level of integration between the image sensor and processor. The need for image processing and the efficiency of the processor will be balanced when making the choice of processor and developing power management strategies.

A simple demonstration of spatial averaging was implemented in the C6211 DSK. A 64x64 pixel image (fig. 2) was reduced to a 12x10 image (fig. 3). Early generations of the retinal prosthesis will have approximately 100 pixels. Future image processing work will focus on the real-time implementation of these algorithms and hardware integration with a standard CCD camera.

Fig. 2 - 64x64 pixel image, input to the spatial average program.

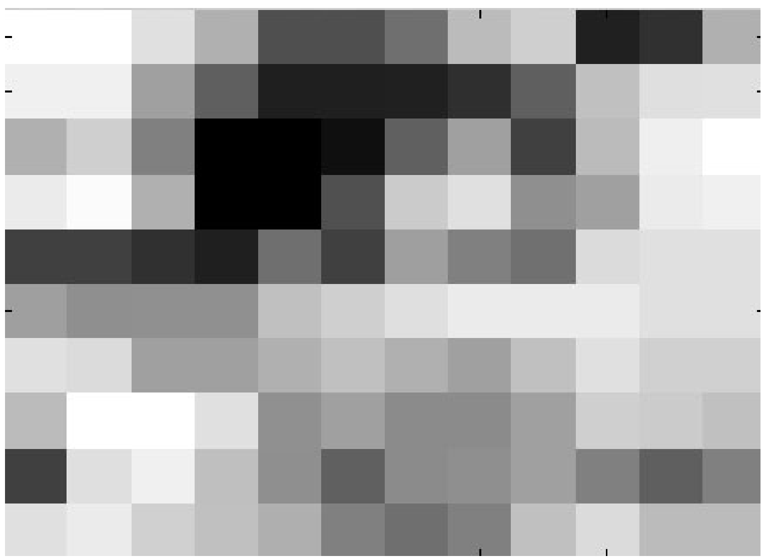

Fig. 3 - Spatial average of previous image, reduced to 12x10 pixels, approximately the density of the first generation retinal implants.