Portable Central Vision Enhancement System for Macular Degeneration Patients

Imperial College London

Newcastle University

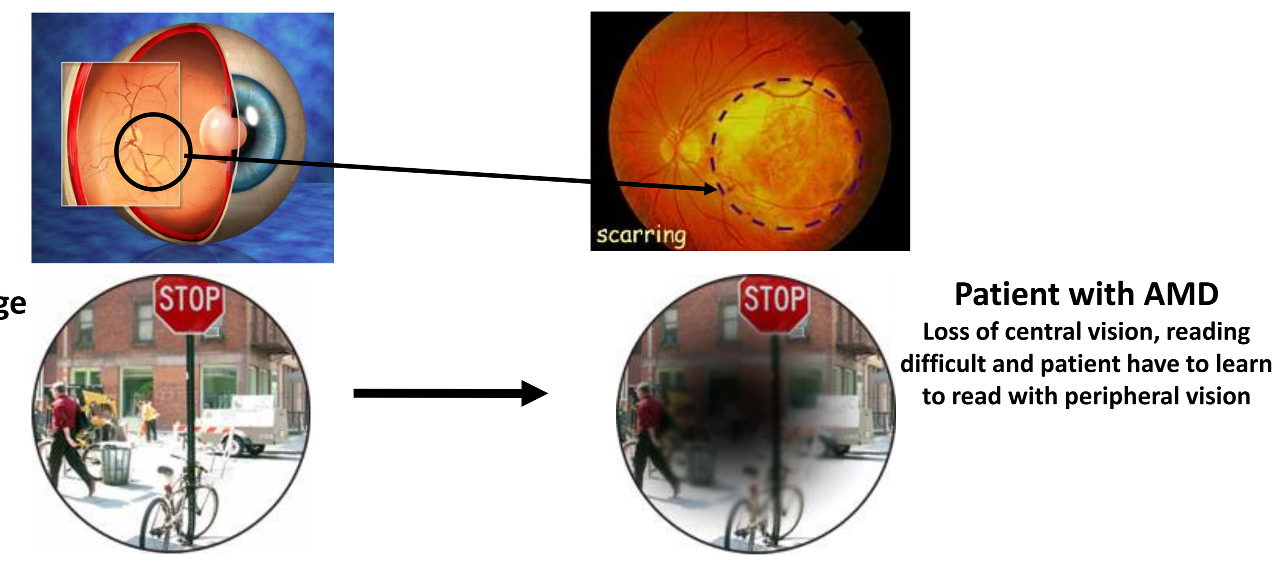
C. Vaniet[1], W. Al-Atabany[1], P. Degenaar[1,2]

[1]Inst. of Biomedical Engineering, [2] Dep. of Neuroscience. Imperial College London

chloe.vaniet09@imperial.ac.uk

Introduction

Vision is a highly important sensing mechanism for humans. As such, a large part of the brain is dedicated to visual processing. People with visual acuity impairment suffer from a range of problems affecting their mobility and quality of life. According to the World Health Organization (WHO), it is estimated that about 135 million people worldwide have a visual impairment, and are said to have Low Vision (LV). There are several causes of low vision pathologies. These pathologies can be divided into two groups, those that mainly produce a loss of visual acuity (macular degeneration and diabetic retinopathy) and those that mainly produce a reduction in the overall visual field–tunnel vision–(retinitis pigmentosa and glaucoma). Other factors that are also affected include contrast sensitivity and adaptation to light changes (night blindness). In this study we are focusing in developing an augmented vision system which aids key feature recognition for patients with macular diseases.



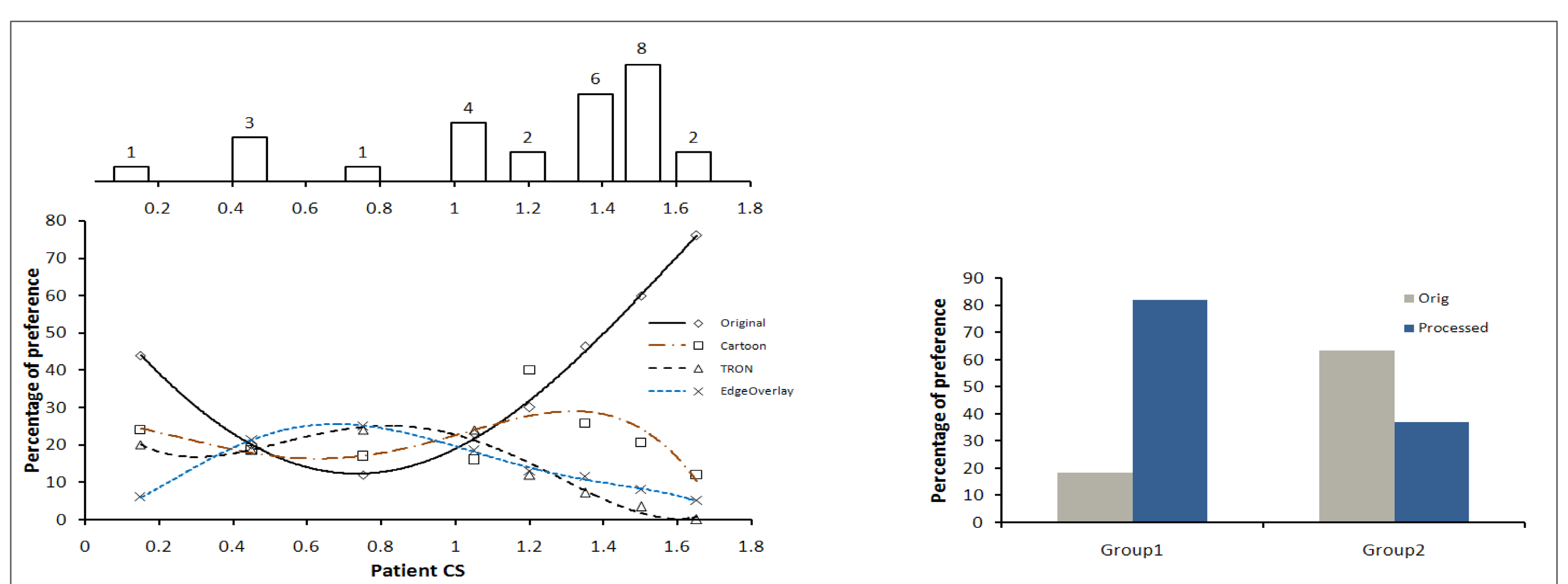
Objective

The critical long term aim is to develop portable, wearable system which can be used in daily tasks. Early phase systems may be initially used in static situations where the user is stationary, but nevertheless, the electronics and portability will be paramount to uptake. Key to this will be the ability to perform advanced image processing tasks with high efficiency, thus requiring minimal (heavy, bulky) battery support.

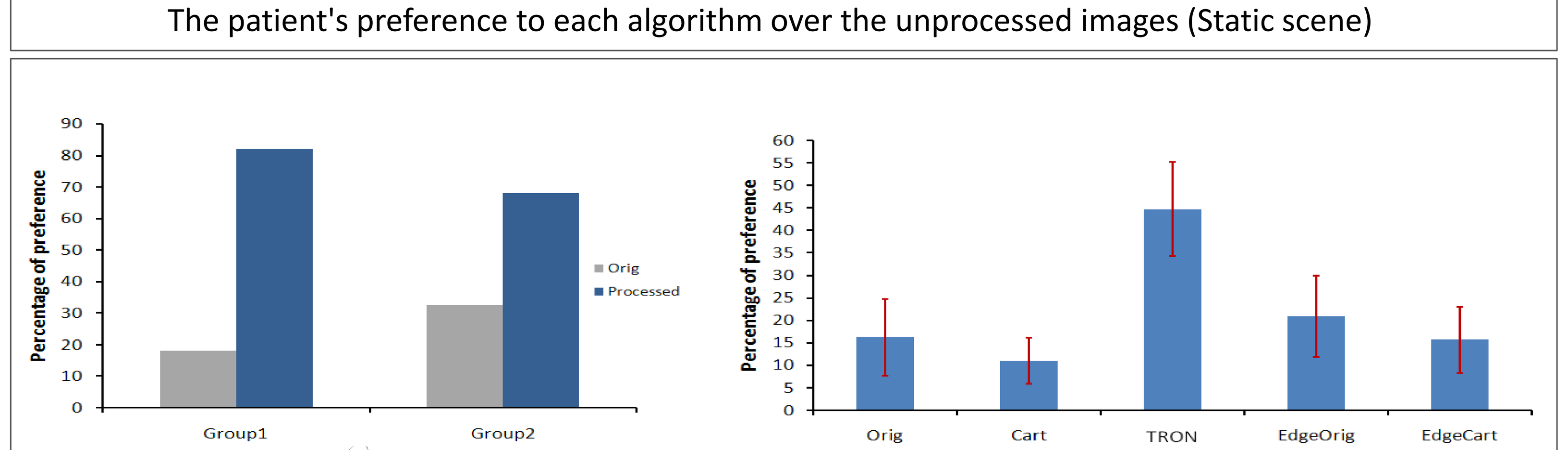
Much of the processing tasks such as ascertaining spatial derivatives and anisotropic filtering can performed using convolution operators. These can consume large amounts of computational power on standard CPU/FPU systems. Thus, we focused our interest on parallel processing architectures. With the new generation of GPU which are now programmable graphics hardware thanks to programmable stages in the graphics pipeline it is possible to offload intensive computations traditionally handled by the CPU to the GPU. That is why we focused our study on the GPU.

Preliminary evidence from Low vision patient trials

27 patients were tested at the Oxford Eye hospital, John Radcliffe Hospital UK. 9 were diagnosed with Retinitis Pigmentosa (RP), 1 each with Pseudoxanthoma Elaspicum and Lebers Hereditary Optic Neuropathy and the remaining had macular pathologies predominantly Stargardt's disease. Median visual acuity (VA) in the better eye for the sample was 6/36 (Range: 6/120-6/6) and the median contrast sensitivity (CS) in the better eye was 1.20 (Range: 0.15-1.65).



The patient's preference to each algorithm over the unprocessed images (Static scene)

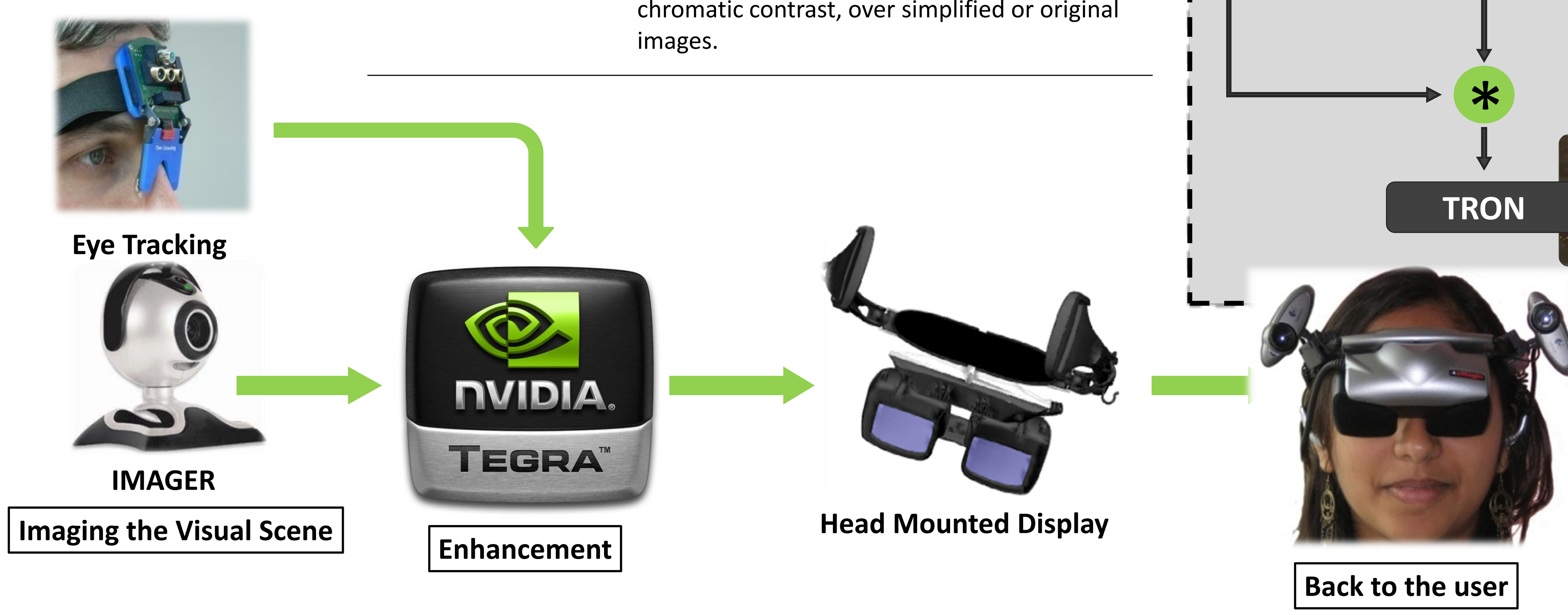


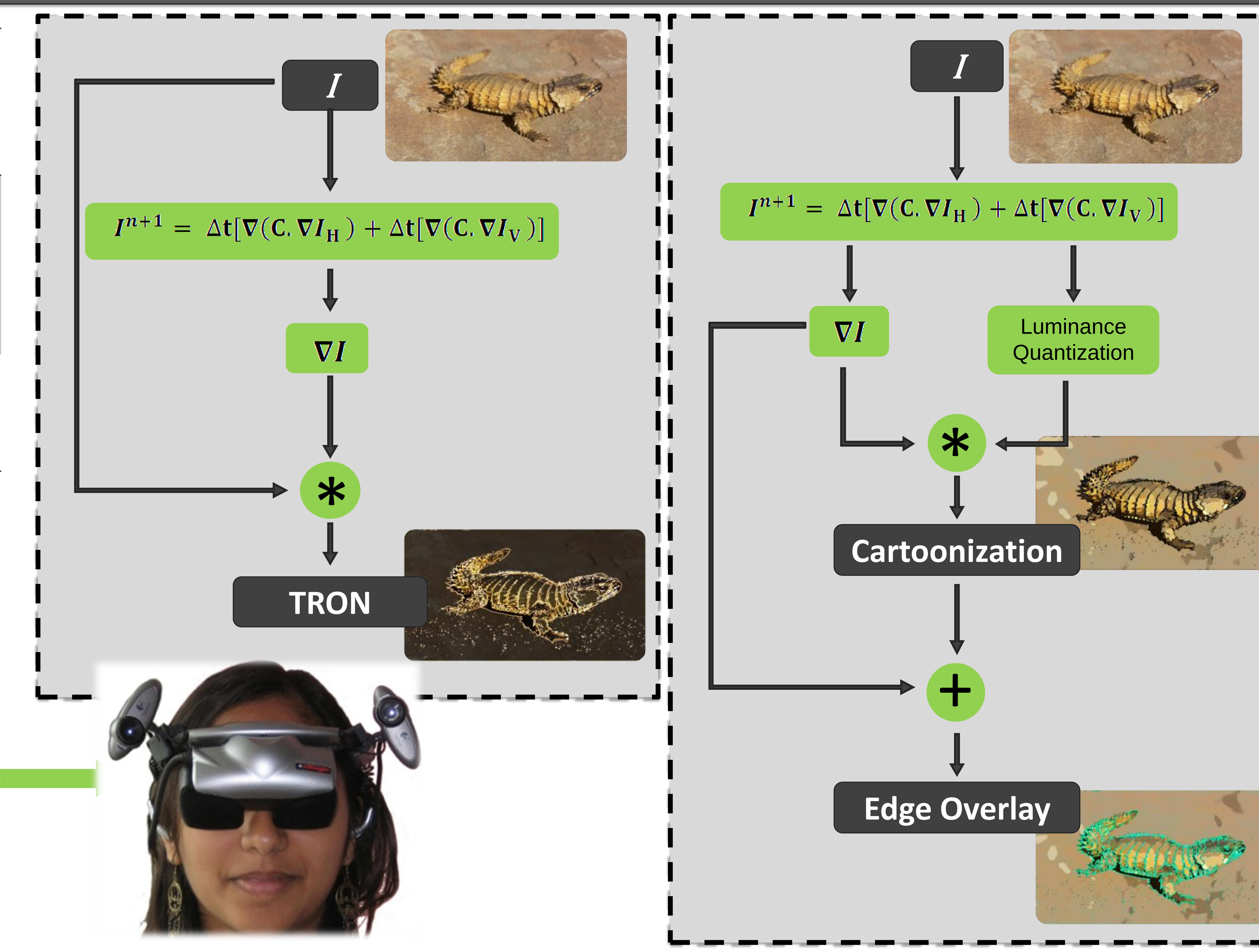
The preference to video processed over the unprocessed

Mobile vision processing system

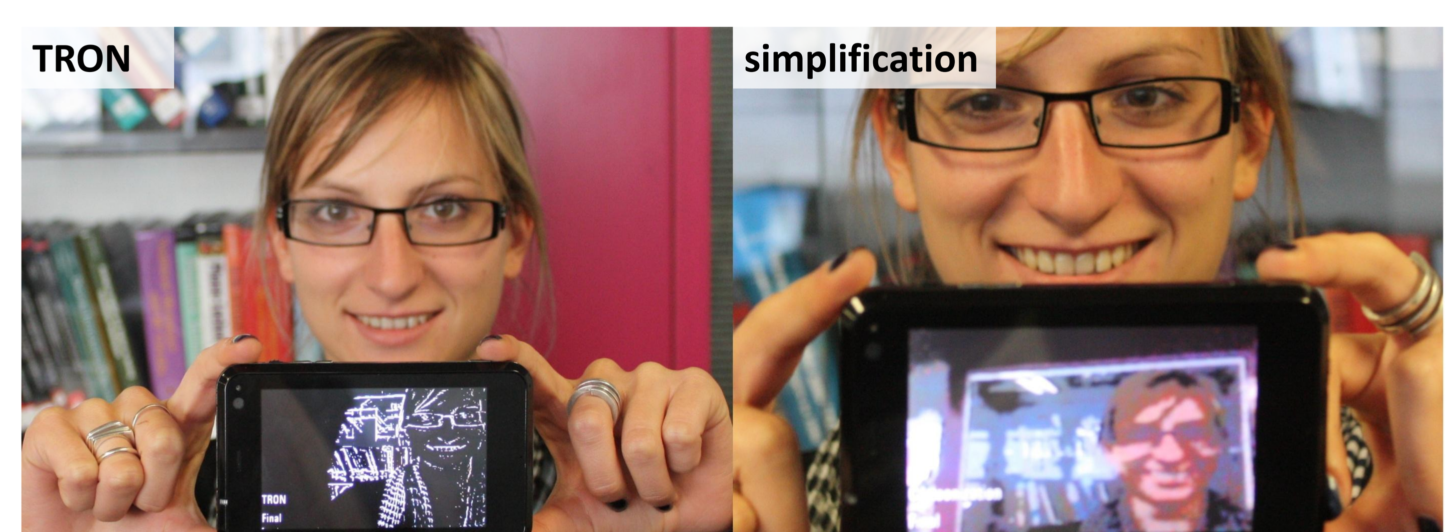
Augmented vision systems will largely enhance the remaining vision of the patient. For macular degeneration, the key tasks will be to enhance landmark recognition, and face recognition. The two critical factors to patient wellbeing i.e. mobility and social contact.

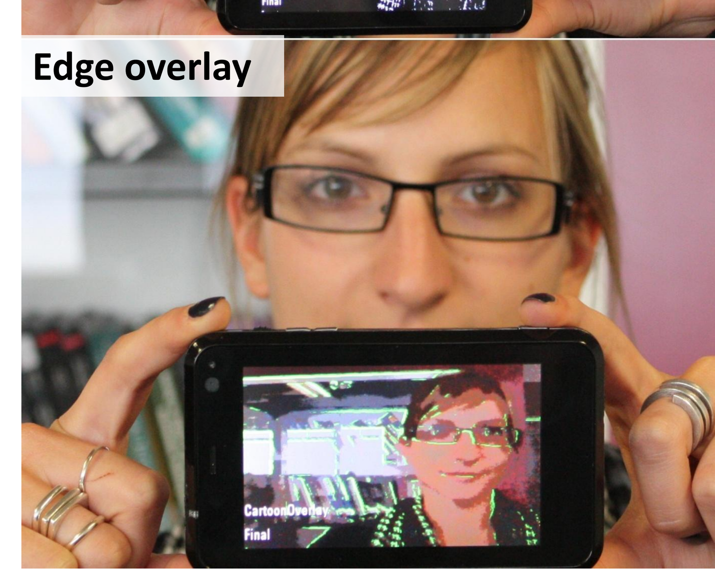
Cartoonization	creates stylized images that facilitate viewer recognition of the shapes by reducing visual clutters such as shadows and textures details.
TRON (Tinted Reduced Outlined Nature)	Focuses on increasing the contrasts between objects by highlighting the edges of the moving objects or the edges between distinguish objects while suppressing the other homogeneous pixels in the scene.
Edge Overlay	Overlays the extracted edges, using optimized chromatic contrast, over simplified or original images.





Hardware Implementation and Performance Results





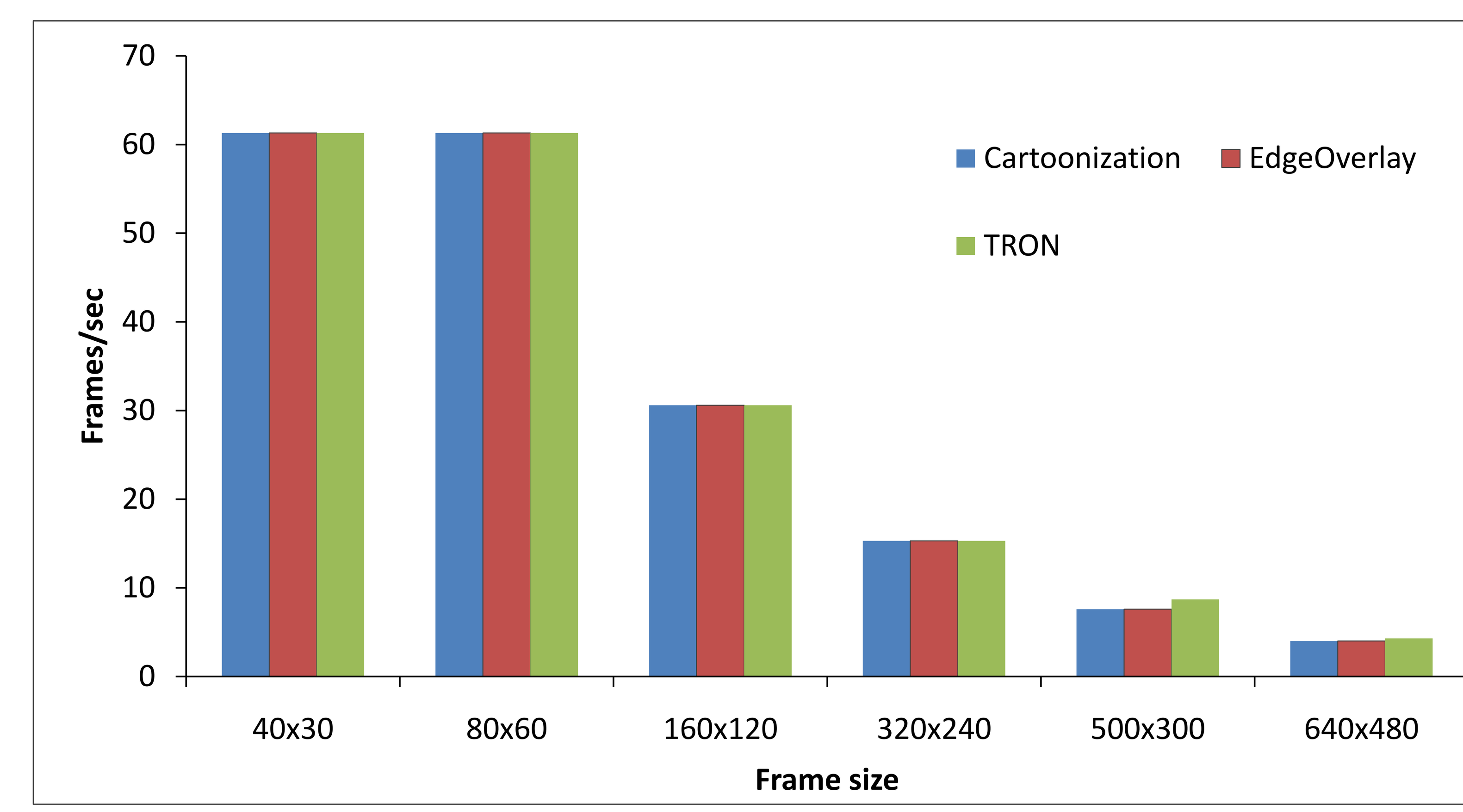
All implementations and measurements were done on the Concorde mobile device. The Concorde is Nvidia's Tegra Smartphone reference design containing the Nvidia Tegra system-on-a-chip.

In terms of development, the image processing operations were implemented using the OpenGL ES 2.0 API and OpenGL Shading Language (GLSL). The program was executed on the Tegra platform with the help of the Nvidia Tegra Application Developers' Software Development Kit (SDK).

Our program performs image processing of a live camera image without the data ever leaving the GPU.

To evaluate the performance of the GPU, we measured the time needed to perform the entire algorithms. Firstly, we measured the frame rate of each algorithm for different image sizes. And we noticed that the frame rate is the same for all algorithms considering a particular image size.

Secondly, we compared the time performance of the GPU with the one of the CPU.



For the two smaller images the frame rate is around 61 fps which is the maximum value that the GPU can reach. For bigger image sizes the frame rate rapidly becomes really low (around 7fps for 500x300 and around 4fps for 640x480). However, with the release of the Tegra II, we can expect to obtain results much closer to real time.

Regarding the comparison with the CPU, we observed that for an image size fixed at 640x480, the GPU is around 2.5 times faster than the CPU. We got 1.6 fps for the entire algorithm running on the CPU compared to around 4 fps on the GPU.

Future works

In the Neurobionics group, Imperial College, researchers are developing optogenetic prostheses for the fully blind.

Optogenetic retinal prosthesis will require the genetic re-engineering of the retinal ganglion cells to express light sensitive channelrhodopsin proteins. The portable processor will need to support both the image enhancement/retinal processing and drive the optoelectronic stimulator

Acknowledgements

We would like to acknowledge and thank the Royal Society Research fun and both the Engineering and Physical Sciences Research Council, and the Biology and Biotechnology research councils for financial support, The Egyptian government for supporting a PhD programme and NVidia for donating the Tegra development platform.

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