EECS 598 013 Intro to Embedded Systems Research Project Proposal

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Goal: Build a system that reduces energy consumption for machine vision applications while maintaining high accuracy through biologically inspired non-uniform image sampling and a scene cache.

Problem Description: Machine vision systems are key components of many important current and upcoming technologies such as facial recognition and autonomous vehicles. These systems are not highly optimized for low-power consumption limiting their potential applications in mobile, battery-powered devices. Biological systems, however, are highly optimized to reduce energy consumption [1].

Related Work: Recent work has had success in reducing machine vision power while maintaining accuracy by applying the biological principles. Most machine vision systems capture images at uniform resolution regardless of whether the data in those sampled pixels are important to the classification task. The human eye however, consists of one small region of high visual sensitivity, the fovea, while the rest of the visual field has much lower sensitivity. By making a machine vision system that selectively samples only the important visual regions at high quality researchers reduced energy consumption by 81% with less than 1% loss in accuracy [2].

Project Innovation: The goal of this project is to expand on digital foveation by applying further biological principles. Biological vision systems overcome having limited regions of visual accuracy by remembering previously sampled visual data in areas outside of the fovea. This project will implement a scene cache for a digital foveation machine vision system, allowing the system to not only choose the location and resolution at which to optimally sample pixels but also the frequency.

Aspects and challenges this project will entail:

- Choosing an appropriate machine vision task: Requires analyzing video. Possibilities include continuous facial recognition, license plate scanning, and object detection for autonomous vehicles.
- Developing a memory structure for storing the scene cache: This must be able to store data values and metadata (e.g., time since sample taken) for heterogeneous pixel regions while also serving as input to machine vision image processing algorithms. Should require minimal computational overhead (to save energy). One possibility is a quad tree representation.
- Developing an effective and efficient machine learning algorithm for choosing when and what data to update in the scene cache. Should have a cost function that trades off energy consumption for application accuracy. Algorithm development will likely be done offline using video training sets. Neural networks, especially convolutional neural networks, have been found useful in image processing. Since convolutional layers are often used to gradually reduce image size using multiple layers, they may integrate well into a heterogeneous scene cache with varying resolutions of data [3].
- Power analysis and verification: Used to compare power consumption of scene cache algorithm to a baseline. Could also be useful in planning algorithm. This could involve simulation and/or implementing the system in hardware.

References

[1] J. E. Niven and S. B. Laughlin, "Energy limitation as a selective pressure on the evolution of sensory systems," *Journal of Experimental Biology*, vol. 211, no. 11, pp. 1792–1804, 2008.

[2] E. S. Lubana and R. P. Dick, "Digital foveation: an energy-aware machine vision framework," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 37, no. 11, pp. 2371–2380, Nov 2018.

[3] Y. Cao, Z. Zhou, W. Zhang, and Y. Yu, "Unsupervised diverse colorization via generative adversarial networks," in *Machine Learning and Knowledge Discovery in Databases*, M. Ceci, J. Hollmén, L. Todorovski, C. Vens, and S. Džeroski, Eds. Cham: Springer International Publishing, 2017, pp. 151–166.