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Small-scale Anomaly Detection in Panoramic Imaging using Neural Models of Low-level Vision

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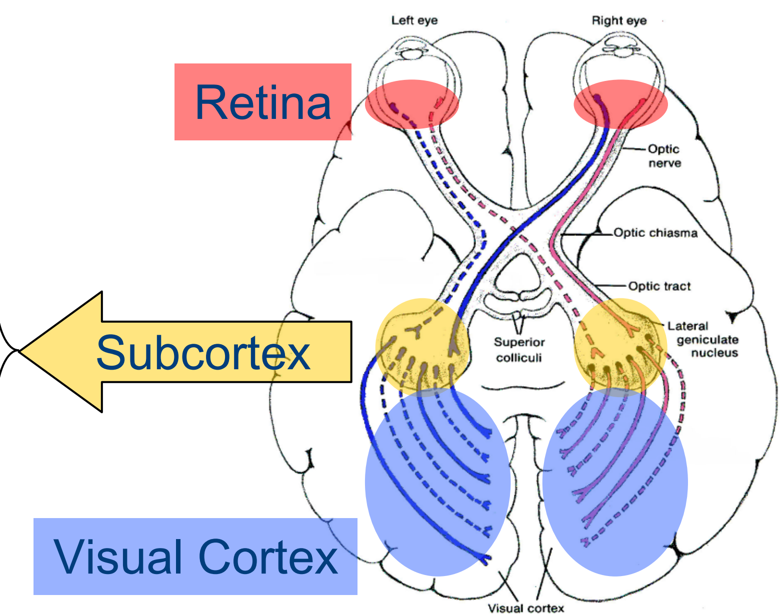
Opportunity

- Models of human senses ready for exploitation
  - New models of low-level vision
  - Rapid, adaptive techniques working on crude stimuli
  - Innovative neural network models
- Exploitation
  - Can we improve anomaly detection in imaging?
  - Real-time, small-scale anomalies in CCTV
  - Panoramic imaging monitored by operators
- Partnership
  - Panoramic imaging: Waterfall Solutions
  - Models of vision: University of Surrey
  - EPSRC: Knowledge Transfer Account (EP/H500189/1)

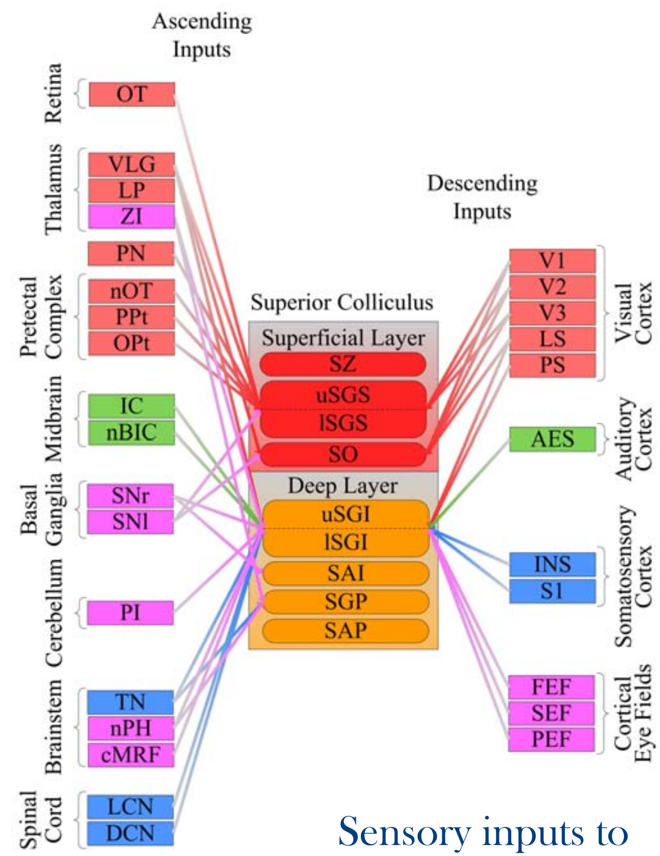
Human Low-level Vision

- How do humans rapidly react to threats?
  - Subcortical sensory processing in the brain
  - Prepares our bodies to react before conscious perception
- Superior colliculus [1,2]
  - Controls gaze shifts [6]
  - Rapid localization
  - For spatial and temporal events [3]
  - Fuses with sounds and touch [2]
- Amygdala [7]
  - Rapid discrimination of threats
  - Learns to react
  - Prepares the body to react



Superior Colliculus

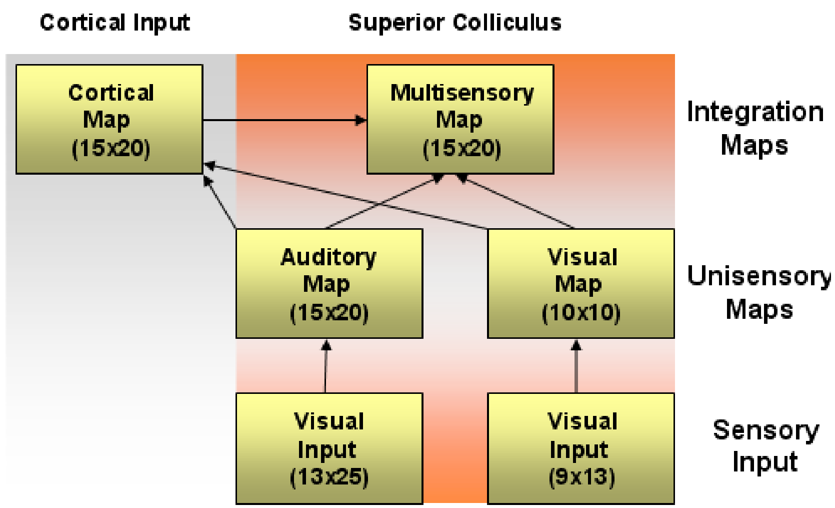
- Layered structure in the midbrain [1]
  - Sensory topographic maps [6]
  - Eye-centered alignment
- Superficial layer
  - Visual input
  - Representation is binocular
  - Sensitive to motion [11-13]
  - Sensitive to contrast [14,15]
- E.g. layering in frogs [3] (optic tectum)
  - Spatial contrast at sharp edges
  - Convex-shaped dark objects (spot the fly)
  - Temporal contrast of moving edges
  - Sudden reduction in illumination (predator's shadow)



Sensory inputs to the SC [6]

Model Specification

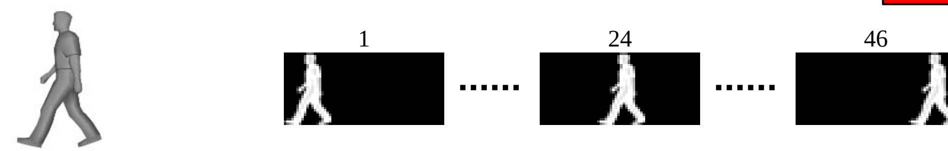
- Previous neuroscience model of the SC [8]
  - Rate-coded neural network
  - Simple layering
  - Weights learnt by competition
- Achieved
  - Localization on abstract data
  - Multisensory integration
- Adaptation
  - Could learn to localize different patterns
- Binocular, rapid localization of anomalies
  - Ideal study on anomaly detection in imaging: small-scale movement



Neural network model [8]

Pilot Experiment

- Can the map used in the SC model detect walking people?
  - 768 by 576 pixels images: grayscale intensity values as input to the map
  - Mosaic of 12 by 18 maps, each with 64 by 2 neurons
  - Trained on a small walking silhouette (from a 3d model)



a) 3-dimensional template

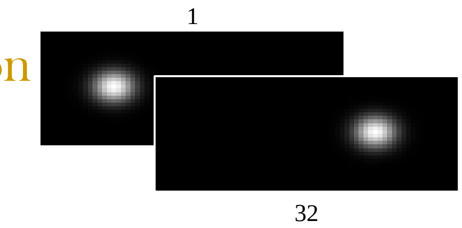
b) Sequence of training images used

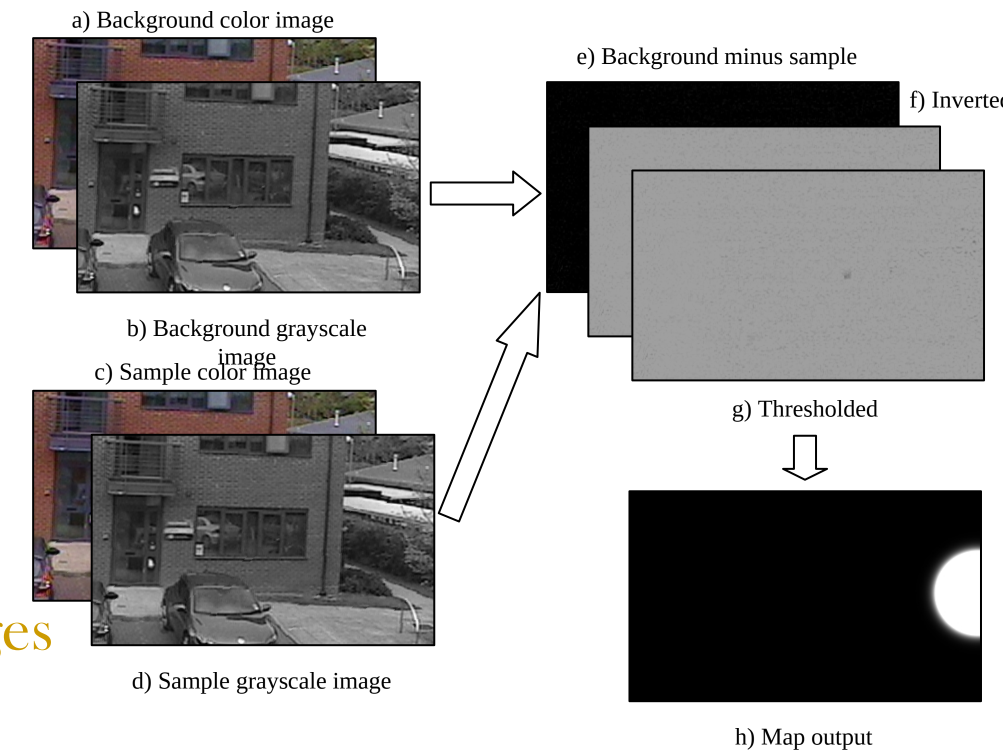
- Localized person (red circle)
  - When obscured by trees 10%
  - When in clear view 24%
  - Total detection rate of 21%; false alarms: 0
- But low detection rate, if no false alarms
  - Input relied upon pixel intensity (dark vs. light clothes)
  - Silhouette was too specific, only detects walking
  - No detection when on boundary between maps

Promising approach, but too specific

Generic Small-scale Detection

- Overcome issues in pilot
  - Detect change in the image using background subtraction
  - More generic training pattern for small-scale anomalies
- Pre-processing crudely approximates retina
  - Simple and rapid
  - But subject to noise
- Steps:
  - a), b) grayscale background
  - c), d) grayscale sample
  - e) subtraction
  - f) inverted (change is high)
  - g) threshold
  - h) topographic map
- Applied to panoramic images





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Panoramic Imaging

- Real-time combination of three cameras
  - Cylindrical warp of overlapping images [22]: 100° horizontal field of view
- Scenes designed to include small-scale or obscured targets
  - Includes 'large-scale' movement of people and cars
  - But also small-scale (normally undetectable) movement: head pop
- Mosaic of maps
  - 1344 by 580 pixels images, split into 64 by 32 pixels for each map
  - Mosaic of 21 by 18 maps, each with 64 by 2 neurons

Look for the head pop

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Panoramic Detection Experiments

- Designed to test the capability of the technique
  - Movement partially obscured which is visible in as little as 3 pixels

Sequence	Description	Frames	Detect Obscured	Detect Clear	False Alarms
1	Person walking behind a tree and parked motorbike	70	56%	100%	0
2	Person crouched behind a car, stands up to be half visible, moves, crouches	56	63%	*	0
3	Person standing out of view behind a corner who then pops their head out	32	84%	*	3
4	Person standing out of view behind a corner who then pops their head out	61	100%	*	28

* Target always obscured

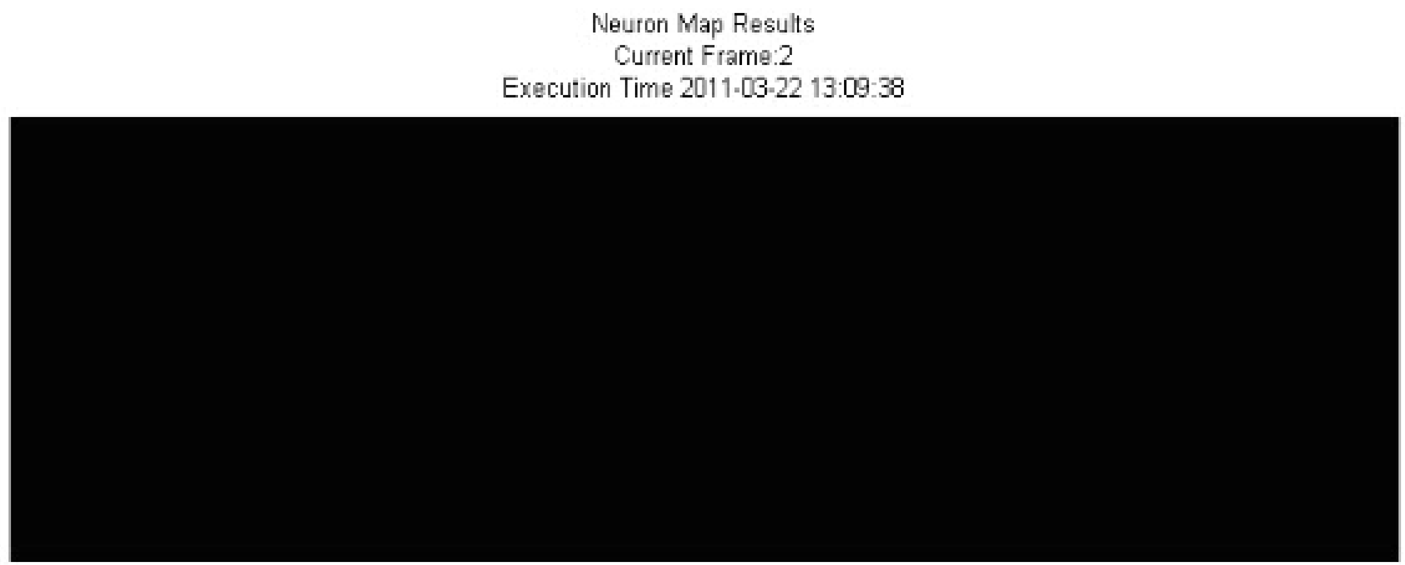
On these constrained sequences: good detection rate, low false alarms

Something More Challenging

- Sequences so far are not realistic
  - Picked to test ability, not to test for issues
  - Longer sequence used which includes significant noise
- Low light scene with various anomalies
  - Person walking towards camera, obscured, hiding and full view
  - Person starts visible (head) at 1 pixel, grows to (full view) 68 pixels

Look for person hiding →

Example


Neuron Map Results
Current Frame:2
Execution Time 2011-03-22 13:09:38

Results

- Rapid detection of obscured and small-scale movement
  - Beyond the capability of conventional techniques
  - But has a high false alarm rate

Sequence	Description	Frames	Detect Obscured	Detect Clear	False Alarms
5	Person behind a parked car (head 1 pixel) Walks towards the camera Passes behind signs; hides in a bush Also a fluttering flag Low light conditions with moving clouds	821	Person: 27%	Person: 41% Flag: 46%	859

Maximum 4 false alarms per frame

Demonstrated: small-scale detection, but high false alarms

Summary

- Biologically-inspired technique
  - Human low-level vision
  - Sensitive to small and large-scale motion and contrast
  - Neuroscience model using neural networks
- Applied to panoramic imaging
  - Demonstrated generic capability to detect movement
  - Particularly small-scale or obscured movement
  - Can be tuned to shape
- Limitations
  - Simple pre-processing (background subtraction)
  - Generic pattern leads to high false alarms
  - May be overcome by improved biological model
  - Temporal contrast detection built into the retina
- Opportunities
  - Improved biological model
  - Link to audio signals [23]

Selected References

[1] King, A. J., "The Superior Colliculus," Current Biology, 14(9) R335-R338 (2004).

[2] Stein, B. E. and Meredith, M. A., [The Merging of the Senses], A Bradford Book, MIT Press, Cambridge, MA., (1993).

[3] Lettvin, J. Y., Maturana, H. R., Mcculloch, W. S. and Pitts, W. H., "What the Frog's Eye Tells the Frog's Brain," Proceedings of the IRE, 47(11) 1940-1951 (1959).

[6] May, P. J., [The Mammalian Superior Colliculus: Laminar Structure and Connections], Buttner-Ennever, J.A. (Ed), Progress in Brain Research: Neuroanatomy of the Oculomotor System, Volume 151, Elsevier, 321-378 (2006).

[7] Öhman, A., Flykt, A. and Esteves, F., "Emotion Drives Attention: Detecting the Snake in the Grass," Journal of Experimental Psychology: General, 130(3) 466-478 (2001).

[8] Pavlou, A. and Casey, M. C., "Simulating the Effects of Cortical Feedback in the Superior Colliculus with Topographic Maps," Proceedings of the International Joint Conference on Neural Networks (IJCNN) 2010, (2010).

[11] Sterling, P. and Wickelgren, B. G., "Visual Receptive Fields in the Superior Colliculus of the Cat," Journal of Neurophysiology, 32(1) 1-15 (1969).

[12] Rauschecker, J. P. and Harris, L. R., "Auditory and Visual Neurons in the Cat's Superior Colliculus Selective for the Direction of Apparent Motion Stimuli," Brain Research, 490(1) 56-63 (1989).

[13] Wallace, M. T., McHaffie, J. G. and Stein, B. E., "Visual Response Properties and Visuotopic Representation in the Newborn Monkey Superior Colliculus," Journal of Neurophysiology, 78(5) 2732-2741 (1997).

[14] Prévost, F., Lepore, F. and Guillemot, J. P., "Spatio-temporal Receptive Field Properties of Cells in the Rat Superior Colliculus," Brain Research, 1142 80-91 (2007).

[15] Schneider, K. A. and Kastner, S., "Visual Responses of the Human Superior Colliculus: A High-Resolution Functional Magnetic Resonance Imaging Study," Journal of Neurophysiology, 94(4) 2491-2503 (2005).

[22] Sadler, J. R. E., Davis, J. and Hickman, D. L., "A Compact Wide-area Surveillance System for Defence and Security Applications," Proceedings of SPIE Defense, Security, and Sensing Conference 2011 on Enhanced and Synthetic Vision, 8042B (2011).

[23] Casey, M. C., Pavlou, A. and Timotheou, A., "Mind the (Computational) Gap," Proceedings of the UK Workshop on Computational Intelligence (UKCI 2010), (2010).

Thank you

Questions?

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