

Summary

- We present a reinforcement learning model of visual attention that **integrates bottom-up and top-down gaze control strategies** in a single architecture.
- The model was originally designed as a model of **gaze following**.
- The model **transitions** from a **mainly bottom-up** to a **combined bottom-up and top-down** control strategy as it learns to follow gaze.

Problem statement

- There is interest in models of visual attention that integrate both bottom-up as well as top-down influences [1, 2, 3].
- Our aim is to show that our reinforcement learning model of gaze following [4, 5] does this, and in a developmental fashion.

A reinforcement learning model of gaze following

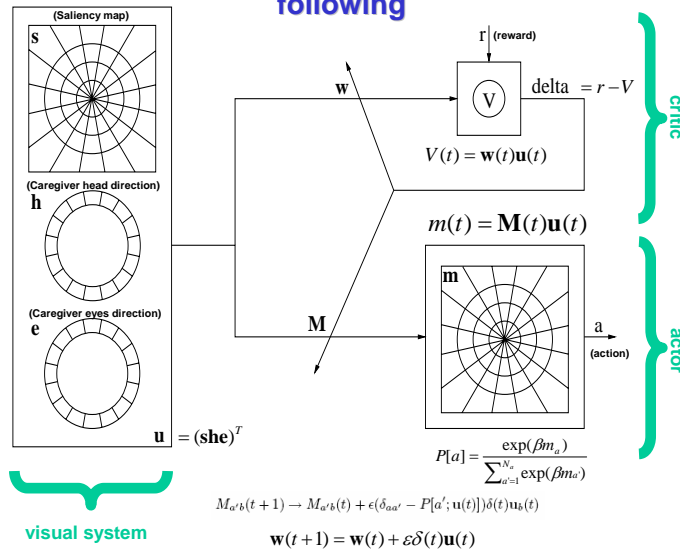


Figure 1. Details of our actor-critic reinforcement learning model of gaze following.

Bottom-up and top-down gaze control

- **Bottom-up** signals: Derived directly from saliencies in the visual input. (from the **s** component of **u**).
- **Top-down** signals: Derived from a (learned) decoding of the other person's head and eyes direction to paths along their line of view. (from the **h** and **e** components of **u**).

Conclusions

- The developmental model presented shows how **experience can drive the transition** to incorporate top-down gaze control.
- The model is being used to explore other aspects of **gaze following** [8, 9].

Training/testing scheme

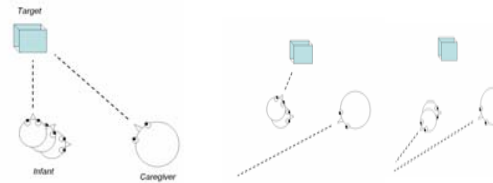


Figure 2. Training setup: infant and caregiver start trial facing each other, with caregiver looking at an object. Trials last 10 time step, equivalent to 10 seconds.

Figure 3. Test setup and possible infant responses. Left: infant follows saliency (bottom-up signal). Right: infant follows gaze (top-down signal).



Results

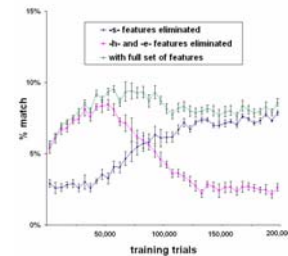


Figure 4. Percentage match between the selected action and the action with highest action value in **m** (results correspond to test setup described in Fig. 3). At first, visual saliencies have a strong impact on the action selected. With learning, the influence is complemented by the top-down influences of the other person's head and eye direction. Standard errors indicated after 10 repetitions.

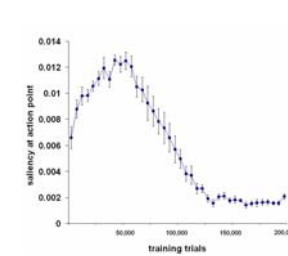


Figure 5. As the model learns to direct its attention to visual saliency, the saliency at the location where attention is directed (action point) grows (results correspond to test setup described in Fig. 3). Then, as the model follows gaze instead of the "imaginary object" behind the infant, this saliency decays. Standard errors indicated after 10 repetitions.

References

- [1] Itti, L., & Koch, C. (2001) Computational modeling of visual attention. *Nature Reviews Neuroscience*, 2:194-203.
- [2] Zelinsky, G., Zhang, W., Yu, B., Chen, X., & Samaras, D. (2005) The role of top-down and bottom-up processes in guiding eye movements during visual search. *Nineteenth Annual Conference on Neural Information Processing Systems (NIPS'05)*, Vancouver, B. C., Canada.
- [3] Navalpakkam, V. & Itti, L. (2005) Modeling the influence of task on attention. *Vision Research* 45:205-231.
- [4] Jasso, H., Triesch, J., Teuscher, Ch., & Deák, G. O. (2006) A reinforcement learning model explains the development of gaze following. *Seventh International Conference on Cognitive Modeling (ICCM'06)*, Trieste, Italy.
- [5] Fasel, I., Deák, G. O., Triesch, J., and Movellan, J. R. (2002) Combining embodied models and empirical research for understanding the development of shared attention. *Second International Conference on Development and Learning, (ICDL'02)*, Cambridge, MA, USA.
- [6] Sutton, R.S., and Barto, A.G. (1998). *Reinforcement Learning: An Introduction*. MIT Press.
- [7] Dayan, P., & Abbott, L. F. (2001). *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. Cambridge, MA, USA: MIT Press.
- [8] Triesch, J., Jasso, H., Deák, G. O. (2006) Emergence of mirror neurons in a model of gaze following. *Fifth International Conference on Development and Learning (ICDL'06)*, Bloomington, IN, USA.
- [9] Jasso, H., Triesch, J. (2006) Using eye direction cues for gaze following – A developmental model. *Fifth International Conference on Development and Learning (ICDL'06)*, Bloomington, IN, USA.