A Reinforcement Learning Model of Selective Visual Attention *

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ABSTRACT

This paper proposes a model of selective attention for visual search tasks, based on a framework for sequential decision-making. The model is implemented using a fixed pan-tilt-zoom camera in a visually cluttered lab environment, which samples the environment at discrete time steps. The agent has to decide where to fixate next based purely on visual information, in order to reach the region where a target object is most likely to be found. The model consists of two interacting modules. A reinforcement learning module learns a policy on a set of regions in the room for reaching the target object, using as objective function the expected value of the sum of discounted rewards. By selecting an appropriate gaze direction at each step, this module provides top-down control in the selection of the next fixation point. The second module performs "within fixation" processing, based exclusively on visual information. Its purpose is twofold: to provide the agent with a set of locations of interest in the current image, and to perform the detection and identification of the target object. Detailed experimental results show that the number of saccades to a target object significantly decreases with the number of training epochs. The results also show the learned policy to find the target object is invariant to small physical displacements as well as object inversion.

1. MOTIVATION

The problem of *visual search* is to find a small object in a large usually cluttered environment (e.g. a pen on a desk). In solving such a problem it is preferable to use wide field-of-view images. On the other hand, small objects require high resolution images, which in combination with the wide field-of-view requirement leads to a very high dimensional input array. *Foveated vision* is nature's method of choice in solving this problem and is a dominant characteristic of the vision system of virtually any vertebrate species with well developed eyes [1]. The *fovea* is anatomically defined as a small, central region on the retina, with a very high density of receptive cells (cones). The density of the receptors (and with it the visual acuity as well) decreases exponentially from the fovea towards the periphery. To make up for any potential loss of information incurred by the decrease in resolution in the periphery, the eyes are rapidly re-oriented via very fast (up to 900°/s), ballistic motions called *saccades*. *Fixations* are the periods between saccades during which the eyes remain relatively fixed, the visual information is processed and the location of the next fixation point is selected.

Foveal image processing reduces the dimension of the input data, but in turn generates an additional sequential decision problem. Choosing the next fixation point requires an efficient gaze control mechanism in order to direct the gaze at the most visually salient object.

From an engineering standpoint, a sequential attention mechanism is a very attractive approach, because it has the potential of requiring only sparse local models [2]. However, the visual attention mechanism raises a plethora of difficult questions. In the first place, since the next fixation point is generally not in the fovea, its selection must be done based on coarse, low resolution visual information, without a thorough understanding of its semantics. The question is then, what low level features are necessary in order to decide what to attend to in the next fixation. Koch and Ullmann [8] propose a saliency map theory which is a task independent, bottom-up model of visual attention. In this framework, Itti and Koch [6], extract three types of feature maps (a color map, an edge map and an intensity map) and fuse them together in a unique map (termed *saliency map*). However, the selection of the next fixation must require some top-down control since low-level visual information is not usually sufficient. Hence the second major question is how to implement a high level, top-down mechanism, to control the low level, reactive attention? Tsotsos et. al. [14] propose a model of visual attention which tries to selectively tune visual processing by means of a top-down hierarchy of winner-take-all processes. Finally, since the vision system samples the environment, some information must be retained from one fixation to the next, and integrate across saccades, to produce a global understanding of the scene.

*First author of this paper is a student.

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A Reinforcement Learning Model Of Selective Visual Attention:

Selective Visual Attention in a Search Task Silviu D. Minut,2000 *Attention and Performance in Computational Vision* Lucas Paletta,2005-01-21 This book constitutes the thoroughly refereed post proceedings of the Second International Workshop on Attention and Performance in Computational Vision WAPCV 2004 held in Prague Czech Republic in May 2004 The 16 revised full papers presented together with an invited paper were carefully selected during two rounds of reviewing and improvement The papers are organized in topical sections on attention in object and scene recognition architectures for sequential attention biologically plausible models for attention and applications of attentive vision **Applications and Techniques in Information Security** Qingfeng Chen,Jia Wu,Shichao Zhang,Changan Yuan,Lynn Batten,Gang Li,2018-10-31 This book constitutes the refereed proceedings of the 9th International Conference on Applications and Techniques in Information Security ATIS 2018 held in Nanning China in November 2018 The 19 full papers were carefully reviewed and selected from 59 submissions The papers are organized in the following topical sections information security information abuse prevention security implementations knowledge discovery and applications **Pattern Recognition and Machine Intelligence** Santanu Chaudhury,Sushmita Mitra,C.A. Murthy,P.S. Sastry,Sankar Kumar Pal,2009-12-02 This book constitutes the refereed proceedings of the Third International Conference on Pattern Recognition and Machine Intelligence PReMI 2009 held in New Delhi India in December 2009 The 98 revised papers presented were carefully reviewed and selected from 221 initial submissions The papers are organized in topical sections on pattern recognition and machine learning soft computing andapplications bio and chemo informatics text and data mining image analysis document image processing watermarking and steganography biometrics image and video retrieval speech and audio processing as well as on applications **Theories of Visual Attention - linking cognition, neuropsychology, and neurophysiology** Søren Kyllingsbæk,Signe Allerup Vangkilde,Claus Bundesen,2015-09-02 The Neural Theory of Visual Attention of Bundesen Habekost and Kyllingsb k 2005 was proposed as a neural interpretation of Bundesen s 1990 theory of visual attention TVA In NTVA visual attention functions via two mechanisms by dynamic remapping of receptive fields of cortical cells such that more cells are devoted to behaviorally important objects than to less important ones filtering and by multiplicative scaling of the level of activation in cells coding for particular features pigeonholing NTVA accounts for a wide range of known attentional effects in human performance and a wide range of effects observed in firing rates of single cells in the primate visual system and thus provides a mathematical framework to unify the 2 fields of research In this Research Topic of Frontiers in Psychology some of the leading theories of visual attention at both the cognitive neuropsychological and neurophysiological levels are presented and evaluated In addition the Research Topic encompasses application of the framework of NTVA to various patient populations and to neuroimaging as well as genetic and psychopharmacological studies Brain-inspired Cognition and Understanding for Next-generation AI: Computational Models, Architectures and

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