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Chapter 1 : Efficient Coding of Visual Scenes by Grouping and Segmentation - CORE

8 Efï¬•cient Coding of Visual Scenes by Grouping and Segmentation Tai Sing Lee and Alan L. Yuille a group of concave indentations (e.g. an egg carton partly ï¬•lled with eggs).

Progress has come about mainly by measuring the electrical activity from parts of the brain that lie between the sensory and motor areas. The neurons in these brain areas operate on a time scale that is not controlled by external events: Put simply, these neurons play neither a purely sensory nor a purely motor role but appear instead to control mental states. My lecture will focus on neurons in the parietal lobe that underlie a simple kind of decision-making? The brain makes a decision when the accumulated evidence represented by the electrical discharge from these neurons reaches a criterion level. These neurons therefore explain both what is decided and when a decision is reached. In addition to mathematical elegance and winning wars, our experiments suggest that this computational strategy may lie at the root of higher brain function. A role for neural integrators in perceptual decision-making. The influence of behavioral context on the representation of a perceptual decision in developing oculomotor commands. Trends in Cog Sci 5: The limit of this never-ending improvement is captured by the notion of optimal performance. Indeed, many behavioral phenomena have been explained as reflecting the best possible control strategy for the given task. In this talk I will summarize the applications of optimal control theory to the study of the neural control of movement. I will then focus on our recent approach, in which the object being optimized is not the average movement trajectory but the sensorimotor loop that generates trajectories online. Applications of this theoretical framework will be illustrated in the context of reaching and via-point movements, eye-hand coordination, bimanual coordination, hitting and throwing tasks, and target perturbation experiments. I will also discuss recent numerical methods for constructing approximately-optimal sensorimotor control laws for complex biomechanical systems. Todorov E Optimality principles in sensorimotor control Review. Nature Neuroscience 7 9: Todorov E and Jordan M Optimal feedback control as a theory of motor coordination. Nature Neuroscience 5 Todorov E Cosine tuning minimizes motor errors. Harris C and Wolpert D Signal-dependent noise determines motor planning. Identification of the parameters proceeds in a Bayesian framework given the known, deterministic inputs and the observed responses of the system. We develop this approach for the analysis of effective connectivity using experimentally deigned inputs and fMRI responses. In this context, parameters correspond to effective connectivity and, in particular, bilinear parameters reflect the changes in connectivity induced by inputs. The ensuing framework allows one to characterise fMRI and EEG experiments, conceptually as an experimental manipulation of integration among brain regions by contextual or trial-free inputs, like time or attentional set that is perturbed or probed using evoked responses to trial-bound inputs like stimuli. As with previous analyses of effective connectivity, the focus is on experimentally induced changes in coupling c. However, unlike all previous approaches to connectivity in neuroimaging, the causal model ascribes responses to designed deterministic inputs, as opposed to treating inputs as unknown and stochastic. Friston KJ, Penny W. Posterior probability maps and SPMs. Bayesian estimation of dynamical systems: Classical and Bayesian inference in neuroimaging: Download the lecture text pdf here Nov. Population coding is also a stochastic representation of information. These subjects are analyzed in terms of probability theory and statisticBayesian and non-Bayesian. The present lecture will give an understandable overview of dynamics of neural learning and self-organization, as well as statistical theory of population coding in terms of Fisher information and information geometry. The role of Bayesian statistics will be elucidated in wider perspectives. No prior knowledge on information geometry is required. The lecture addresses those topics as 1 dynamics of self-organization 2 stochastic equation for neural learning 3 singular structure in neural networks 4 Fisher information in population coding 5 synchronization and higher-order interaction of neurons. Sakai, Synchronous firing and higher-order interactions in neuron pool, Neural Computation, 15, , H. Amari, Information-geometric measure for neural spikes, Neural Computation, 14, , S.

Amari, Population coding with correlation and an unfaithful model, Neural Computation, 13, , S. Amari, Natural gradient works efficiently in learning, Neural Computation, 10,, A. Amari, Formation of topographic maps and columnar microstructure, Biological Cybernetics, 35, , S. Takeuchi, Mathematical theory on formation of category detecting nerve cells, Biological Cybernetics, 29, , Download the lecture text pdf here Download the lecture slides, part 1 ppt here , part 2 ppt here Nov. David Knill "Bayesian models of sensory cue integration" Probability theory provides a calculus for constructing optimal models of perceptual inference in the face of uncertain sensory data. These models characterize how a perceptual system "should" work. We have been using the framework to also construct models of perceptual performance - how the brain actually does work. I will describe how the probabilistic approach applies to the problem of integrating multiple sources of sensory information sensory cues about objects in the world. In particular, I will describe a Bayesian taxonomy of strategies for integrating depth cues stereo, shading, etc. I will also describe apsychophysical approaches that allow us to test and compare different Bayesian theories of cue integration. I will illustrate the theory with specific examples from perceptual phenomonology and psychophysics on depth cue integration. Specific examples discussed will include simple weighted averaging of the information provided by different cues, how the weights in such a scheme depend on cue uncertainty, nonlinear forms of cue integration, the role of prior assumptions about the world in cue integration and integrating information over time. Each new theoretical idea discussed will coupled with examples of psychophysical experiments designed to test the theoretical redictions. Rajesh Rao "Probabilistic Models of Cortical Computation" There is growing evidence that the brain utilizes probabilistic principles for perception, action, and learning. How such principles are implemented within neural circuits has become a topic of active interest in recent years. In this lecture, I will review two models of cortical computation that my collaborators and I have investigated over the past few years. The first model, based on the statistical principle of predictive coding, ascribes a prominent role to feedback connections in cortical computation. It provides new interpretations of neurophysiological properties such as non-classical receptive field effects. The second model describes how networks of cortical neurons may perform hierarchical Bayesian inference by implementing the belief propagation algorithm in the logarithmic domain. In this model, the spiking probability of a noisy cortical neuron approximates the posterior probability of the preferred state encoded by the neuron. I will discuss the application of this model to understanding cortical phenomena such as direction selectivity, decision making, and attentional modulation. Download the lecture text pdf here Download the lecture slides ppt here Nov. Konrad Koerding "Bayesian combination of priors and perception: Optimality in sensorimotor integration" When we move our hands we have to contend with variability inherent in our sensory feedback. As our sensors do not provide perfect information we can only estimate our hands position. Bayesian statistics defines that to generate an optimal estimate, information about the distribution of positions the prior should be combined with the evidence provided by sensory feedback. I will summarize a number of experiments that show that that humans use such an optimal strategy. In such studies it is usually assumed that people have a certain criterion of optimality; often it is assumed that people want to minimize the mean squared error or maximize the amount of money they earn. In the human sensorimotor system it is possible to measure this optimality criterion that is called utility function. I will review experiments that measure such utility functions. We find that for the range of errors we used the optimality criterion was close to our initial assumptions. The optimality criterion should, however, not only depend on the errors made but also on the effort needed. Which forces had to be held for how long should influence the optimal behaviour. Understanding how people use Bayesian statistics along with understanding what they are trying to optimize in a statistical way is an important step to put human behaviour into a more quantitative framework. Spatial Vision, 16, Wolfgang Maass "Computational Properties of Cortical Microcircuit Models" I will focus on the challenge to understand computations in realistic models for cortical microcircuits, for example computer models of cortical microcircuits based on the detailed experimental data of [Thomson et al,], [Markram et al,], and [Gupta et al,]. It is commonly assumed that such microcircuits are the computational modules of cortical computations see [Mountcastle,], [Silberberg et al,]. Cortical microcircuits can be viewed as special cases of dynamical systems, but as dynamical systems that continuously receive external inputs instead of the case of autonomous dynamical systems that has been studied extensively in dynamical systems theory. I will discuss theoretical results and computer simulations of online computations in such dynamical systems see [Bertschinger et al,], [Maass et al,]. This analysis suggests a new systems-oriented perspective of neural computation and neural coding which complements the classical approaches. It also suggests new methods for the design of experiments and for analyzing data from multi-unit neural recordings. Organizing principles for a diversity of GABAergic interneurons and synapses in the neocortex. Methods for estimating the computational power and generalization capability of neural microcircuits. MIT Press, http: Differential signaling via the same axon of neocortical pyramidal neurons. Stereotypy in neocortical microcircuits. Synaptic connections and small circuits involving excitatory and inhibitory neurons in layers of adult rat and cat neocortex: Barry Richmond "Neural Coding: Determinsim vs stochasticity" Ever since the advent of single neuronal recording, there has been speculation and debate aboutwhat aspects of neuronal responses carry information. It has always been clear that the number of spikes is related to the function of neurons. However, because neuronal responses vary in their rate, it has also seemed likely that the pattern of spikes over time, for example, with changes in rate, also carries information. A lot of recent work has focused on what the natural time resolution for representing the neural spike might be. Under some circumstances such as viewing stationary objects or scenes a time resolution of ms seems adequate, whereas with rapidly changing random stimulus sequences the spikes seem to be considerably more precise, with resolution of under 5 ms. In many circumstances the number of spikes in each response can vary considerably. For interpreting whether spikes are stochastic samples from a rate function or more deterministic, it is critical to understand the relation between the number and patterns of spikes. Taking this relation into account leads to understanding spike trains in terms of order statistics, allowing development of a strategy for decoding stochastic spike trains millisecond-by-millisecond. Further work leads to the observation that spike trains, which often seem stochastic but seldom if ever seem Poisson, can often be modeled as a mixture of nonhomogeneous or rate-varying Poisson processes, making decoding and simulation easy and quick. Wiener and Barry J.

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Chapter 2 : Table of Contents

CiteSeerX - Document Details (Isaac Councill, Lee Giles, Pradeep Teregowda): The goal of this chapter is to present computational theories of scene coding by image segmentation and to suggest their relevance for understanding visual cortical function and mechanisms.

An integrated stereo-based approach to automatic vehicle guidance, Q. Luong Berkeley , J. Weber Berkeley , D. Direct estimation of affine deformations using visual front-end operators with automatic scale selection, Tony Lindeberg KTH. Seeing behind the scene: Analysis of photometric properties of occluding edges by the reversed projection blurring model, Naoki Asada Okayama , Hisanaga Fujiwara Okayama , Takashi Matsuyama Okayama. Saliency maps and attention selection in scale and spatial coordinates: Bayesian decision theory, the maximum local mass estimate, and color constancy, William Freeman Mitsubishi , David Brainard Santa Barbara. Color constancy in diagonal chromaticity space, Graham Finlayson Simon Fraser. Accurate internal camera calibration using rotation, with analysis of sources of error, Gideon Stein MIT. Rigid body segmentation and shape description from dense optical flow under weak perspective, Joseph Weber Berkeley , Jitendra Malik Berkeley. Computation of coherent optical flow by using multiple constraints, Massimo Tistarelli Genoa. Motion from the frontier of curved surfaces, R. Cipolla Cambridge , K. Astrom Lund , P. Reception -- McCormick Hall Courtyard, 6: A unified approach for coding and interpreting face images, A. Lanitis Manchester , C. Taylor Manchester , T. Holyoke , Anand Rangarajan Yale. Locating objects using the Hausdorff distance, William Rucklidge Xerox. Zhu Harvard , Alan Yuille Harvard. Invariant-based recognition of complex curved 3d objects from image contours, B. Combining color and geometric information for the illumination invariant recognition of 3d objects, David Slater Irvine , Glenn Healey Irvine. Perceptual organization in an interactive sketch editing application, Eric Saund Xerox , Thomas Moran Xerox Mosaic based representations of video sequences and their applications, Michal Irani Sarnoff , P. Anandan Sarnoff , Steve Hsu Sarnoff. Structure and semi-fluid motion analysis of stereoscopic satellite images for cloud tracking, K. Volumetric deformable models with parameter functions: Banquet -- New England Aquarium, 7: Buses will return from the Aquarium around Color constancy under varying illumination, G. Finlayson Simon Fraser , B. Funt Simon Fraser , K. On representation and matching of multi-coloured objects, J. Matas Surrey , R. Marik Surrey , J. Deformable Velcro TM surfaces, W. Neuenschwander ETH , P. Fua SRI , G. Szekely ETH , O. Recovering object surfaces from viewed changes in surface texture patterns, Peter Belhumeur Yale , Alan Yuille Harvard. A linear method for reconstruction from lines and points, Richard Hartley GE. Affine surface reconstruction by purposive viewpoint control, Kiriakos Kutulakos Rochester Estimating the tensor of curvature of a surface from a polyhedral approximation, Gabriel Taubin IBM. Hierarchical statistical models for the fusion of multiresolution image data, J. Statistical learning, localization, and identification of objects, J. Hornegger Erlangen , H. Invariant of a pair of non-coplanar conics in space: A comparison of projective reconstruction methods for pairs of views, C. Determining wet surfaces from dry, Howard Mall, Jr. Improving laser triangulation sensors using polarization, J. Clark Heriot-Watt , E. Trucco Heriot-Watt , H. Active fixation using attentional shifts, affine resampling, and multiresolution search, A. Abbott Virginia Tech , B. A method for locating and describing objects, M. Kelly McGill , M. In defence of the 8-point algorithm, Richard Hartley GE.

Chapter 3 : OCNC | OIST Groups

By Tai Sing Lee and Alan L. Yuille Abstract The goal of this chapter is to present computational theories of scene coding by image segmentation and to suggest their relevance for understanding visual cortical function and mechanisms.

Chapter 4 : CVPR | Kurzweil

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Chapter 5 : Advances in Neural Information Processing Systems 19 | MIT CogNet

Probabilistic Approaches to Neural Coding 8 Efficient Coding of Visual Scenes by Grouping and Segmentation Tai Sing Lee and Alan L. Yuille

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