Adaptive sequential feature selection in visual perception and pattern recognition

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Liliya Avdiyenko

In the human visual system, one of the most prominent functions of the extensive feedback from the higher brain areas within and outside of the visual cortex is attentional modulation. The feedback helps the brain to concentrate its resources on visual features that are relevant for recognition, i. e. it iteratively selects certain aspects of the visual scene for refined processing by the lower areas until the inference process in the higher areas converges to a single hypothesis about this scene.

In order to minimize a number of required selection-refinement iterations, one has to find a short sequence of maximally informative portions of the visual input. Since the feedback is not static, the selection process is adapted to a scene that should be recognized. To find a scene-specific subset of informative features, the adaptive selection process on every iteration utilizes results of previous processing in order to reduce the remaining uncertainty about the visual scene.

This phenomenon inspired us to develop a computational algorithm solving a visual classification task that would incorporate such principle, adaptive feature selection. It is especially interesting because usually feature selection methods are not adaptive as they define a unique set of informative features for a task and use them for classifying all objects. However, an adaptive algorithm selects features that are the most informative for the particular input. Thus, the selection process should be driven by statistics of the environment concerning the current task and the object to be classified. Applied to a classification task, our adaptive feature selection algorithm favors features that maximally reduce the current class uncertainty, which is iteratively updated with values of the previously selected features that are observed on the testing sample. In information-theoretical terms, the selection criterion is the mutual information of a class variable and a feature-candidate conditioned on the already selected features, which take values observed on the current testing sample. Then, the main question investigated in this thesis is whether the proposed adaptive way of selecting features is advantageous over the conventional feature selection and in which situations.

Further, we studied whether the proposed adaptive information-theoretical selection scheme, which is a computationally complex algorithm, is utilized by humans while they perform a visual classification task. For this, we constructed a psychophysical experiment where people had to select image parts that as they think are relevant for classification of these images. We present the analysis of behavioral data where we investigate whether human strategies of task-dependent selective attention can be explained by a simple ranker based on the mutual information, a more complex feature selection algorithm based on the conventional static mutual information and the proposed here adaptive feature selector that mimics a mechanism of the iterative hypothesis refinement.

Hereby, the main contribution of this work is the adaptive feature selection criterion based on the conditional mutual information. Also it is shown that such adaptive selection strategy is indeed used by people while performing visual classification.