Study of Human Classification using Psychophysics and Machine Learning

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1 Overview and Introduction

Aim: to reach a better understanding of classification in the human brain
Motivation and questions:

- how does the human brain extract features from visual stimuli and classify them?
- how do machines compare to humans?
- what types of machine learning models may be similar to humans?
- how can the acquired knowledge about humans be used to improve artificial feature extraction and classification?

Method: combination of *psychophysical* and *machine learning* techniques

2 Methodology

A human subject is asked to classify faces according to their gender and the following experimental parameters are recorded:

1. class (i.e. female/male) with its reaction time (RT)
2. confidence rating (CR)

The stimuli are presented sequentially to the subjects using a modified Hanning window ($t_{transient} = 500ms$ and $t_{steady} = 1000ms$) and the subjects are asked to answer as fast as possible for gender, while taking their time for the CR. A training phase precedes the actual classification experiment. Classification error, RT, and CR are then correlated to the mean distance $|\delta|$ of elements from the database to the separating hyperplane (SH) obtained for:

- Support Vector Machine (SVM) and Relevance Vector Machine (RVM)
- Prototype Learner (PROT) and K-means Learner (KMEAN)

3 Databases

3.1 Subject Stimuli

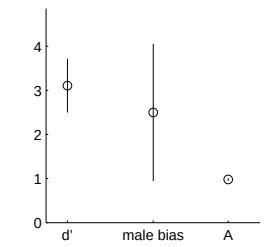
Frontal views of human faces taken from the MPI head database, with removal of obvious cues such as color and size (Graf & Wichmann, BMCV 02) and smoothing in order to eliminate, as much as possible, scanning artifacts. The database is gender-balanced.

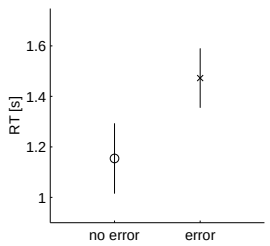
3.2 Machine Input

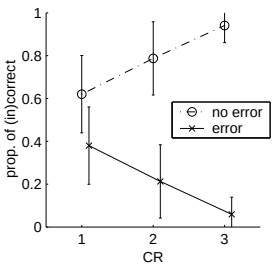
Principal Component Analysis is used to perform *feature extraction* by dimensionality reduction (for a comparative study with Locally Linear Embedding, see Graf & Wichmann, BMCV 02). PCA is applied to the texture and flowfield vector of the face images and performs a dimensionality reduction from $3 \cdot 256^2$ to 200 components.

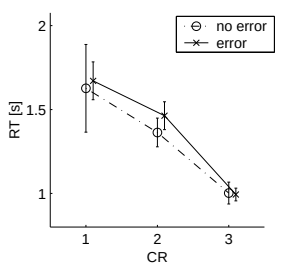
4 Results

4.1 Analysis of Data from Subject



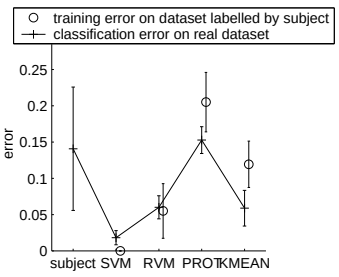


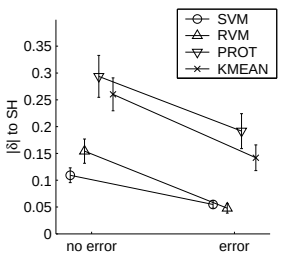


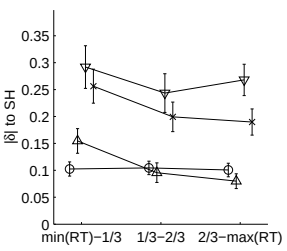


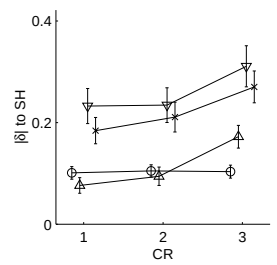
- the value of d' suggests that the discrimination task is easy for the subjects; the latter exhibit a strong male bias
- the RT is higher for an incorrect answer than for a correct one
- a high CR indicates a low classification error, i.e. subjects know when they are right or wrong
- the RT decreases as CR increases

4.2 Correlation of Data between Subject and Machine









- PROT and KMEAN have difficulty to learn the database labeled by the subject and the real one; the opposite applies for SVM and RVM
- elements far from the SH are classified more accurately, faster and with higher confidence than those near to the SH

5 Conclusions and Outlook

- the combination of PCA with SVM and RVM allows accurate learning of the database labeled by the subject, what is not true for PROT or KMEAN
- KMEAN and RVM show the most biological-faithful behavior (steepest slopes, monotonically increasing or decreasing)
- Outlook: study of representations ("special" elements of machine) in a memory experiment