Automated Discovery of Behavioural Patterns in Rodents

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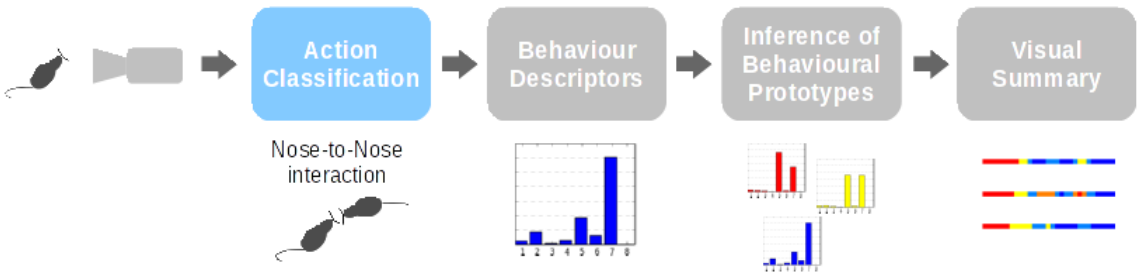
Genetically modified mouse models are now routinely assessed for their behavioural phenotype, as they constitute a valuable tool for translational studies investigating social abnormalities in mental illnesses. Reliable analysis of complex social behaviours comes through the adoption of objective and statistically significant indicators, requiring therefore measures taken over extended time spans. In such investigations, manual scoring of social interactions is still the most important experimental bottleneck, since it is extremely challenging and time consuming. Indeed, long-lasting investigations eliciting long-term behavioural patterns are impractical, and the experimenter is pushed to assess the theories with manageable experiments necessarily short and of limited extent. Moreover, manual scoring is always prone to the risk of subjective judgments due to the experimenter bias, with high impact on repeatability of experiments.

Hence, there is an increasing interest in the development of systems for automated behaviour analysis from videos, enabling long lasting and large-scale experiments. While this opens huge opportunities for high throughput phenotyping, the increasingly wide quantity of collected data force the scientists to face new challenges for their analysis, especially when relevant information cannot be captured by mere statistics. This is often the case when dealing with complex phenomena such as relations, sequences, co-occurring events or repetitive patterns, especially if they are evolving over time.

Aiming at the above issues, we developed a computational framework combining a tracking algorithm able to simultaneously track multiple mice and an automatic system for the analysis of social interactions of multiple interacting mice using a learning-by-examples approach. Tracking was addressed by developing a robust processing pipeline, composed of blob detection, shape segmentation and matching modules, allowing to address the frequent occlusions of mice, which have non-rigid shapes and similar appearance. Tracking results are then used by an automatic behavioural classification algorithm, based on an extension of random forests to the multi-frame case. This multi-frame extension allows exploiting the temporal information at the level of the model rather than at the feature level, in order to recognize behaviours that can be inferred only considering a certain time span. The system is characterized by a great adaptability to the experimenter needs, who can refine existing classes of interaction or create new ones just providing examples, i.e., annotating the behaviours in segments of video. In our system the social interactions are detected on all possible mice pairs and then properly combined to obtain overall behaviours for each mouse. This permits either global analyses in the arena or finer analysis over a specific mouse in a group.

Mice behaviour phenotyping, however, is not only made of mere statistics. While the common trend is to focus on statistics of single actions, sequences of actions and repetitions of behaviours are important elements to characterize behavioural phenotypes. Indeed, looking for patterns of actions can give a richer interpretation of the observed behaviours. For this reason, we propose a mathematical formalism based on a Bayesian Nonparametric model (a Dirichlet Process Mixture of Multinomials) able to capture an appropriate collection of behavioural prototypes in a completely unsupervised way. These prototypes are then used to characterize mice behaviour and to present the user with a high-level aggregation and an intelligible representation of the statistical structure of behaviour, capturing relevant behavioural patterns not known a priori.



The proposed method aims at supporting behavioural scientists in the complex task of understanding important traits of mice behaviour. Indeed, such behaviour-oriented data mining approach could be very useful to get a first understanding of the data, providing new chances for the identification and interpretation of novel complex behavioural traits, and can guide the formulation of hypothesis and the subsequent design of further experiments.

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