A brief review of machine learning techniques in computational ethology.

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Abstract. The increase in the production of behavioral data in the neurosciences, together with technological advances in computer science, have made it possible to automate the analysis of animal behavior, also known as ethology. Scientific literature has coined the term computational ethology to describe the application of computer systems that make use of computer vision and artificial intelligence techniques in the field of ethology. This paper aims to carry out a brief literature review to identify which algorithms and machine learning techniques have been used in problems of ethological analysis of animal models based on video recordings. As a result, it was identified that supervised models are the most common, which still requires extensive manual annotation work by expert observers to build datasets of behavioral data. Advances are needed in terms of terminology as well as model transparency and reproducibility.

Keywords. Animal Behavior, Computational Ethology, Machine Learning, Rodents Behavior Analysis.

1. Introduction

The neurosciences have witnessed an accelerated rate of growth in the production and complexity of available data. The development of animal models as experimental tools can help to understand the neurobiological aspects associated with pathologies of interest [1]. In the field of behavioral neuroscience, the possibility of recording videos of experimental protocols with animal models has resulted in an increase in the production and quality of data for the study of neurobiological correlates between disease states and behavior. The behavioral analysis of animals submitted to experimental tests must be meticulous. To this end, ethology, the science of the biological study of behavior, is used as a tool.

Historically, ethological analyses were carried out manually by trained observers, but there are inherent limitations to this method, such as subjectivity and slowness [2]. Taking advantage of the large amount of data available and recent advances in areas such as artificial intelligence, a new field of research has emerged: computational ethology, which refers to the application of computer vision and machine learning methods to quantify animal behaviors in video recordings in an automated way.

Anderson and Perona [3] propose that a computational ethology system consists of at least three parts: (1) tracking, (2) action classification and (3) behavior analysis. In this sense, for each of these levels of organization of an automated animal behavior analysis system, various machine learning algorithms can be used.

This paper aims to carry out a brief literature review to identify artificial intelligence algorithms and techniques that are being used in the field of computational ethology. In the subsequent sections, the methodology of the literature review will be presented, as well as the main results and their discussion.

2. Methodology

The literature review was based on studies indexed in three databases: Scopus, Web of Science and PubMed. The search was conducted using the following terms: ("computational ethology" OR "computational animal behavior analysis" OR "automated behavior analysis") AND ("deep learning" OR "machine learning"). The search for terms was limited to the contents of the title, abstract and keywords. In all databases, filters were applied for results in English and with open access. Only publications from the last five years were considered.

Eligibility criteria were raised: (1) the study must propose a machine learning solution that uses videos as the main input data; (2) the videos must be typical recordings of controlled behavioral tests in the laboratory, preferably with mammals, excluding humans; (3) the proposed technologies must not involve the use of devices that are in any way invasive to the animals (e.g. physical sensors attached to their bodies). The purpose of these eligibility criteria is to select only works that apply machine learning techniques directly to videos usually recorded in basic research, especially in neuroscience, without the need to implement more specific methods for acquiring videos with more sophisticated equipment and protocols.

The methodology is justified because this text is to be part of a course completion work that aims to develop an automated system for the detection and automatic classification of behaviors in animal models of psychopharmacology.

3. Results

Following the proposed methodology, the search and selection of articles followed the workflow illustrated in Fig 1.

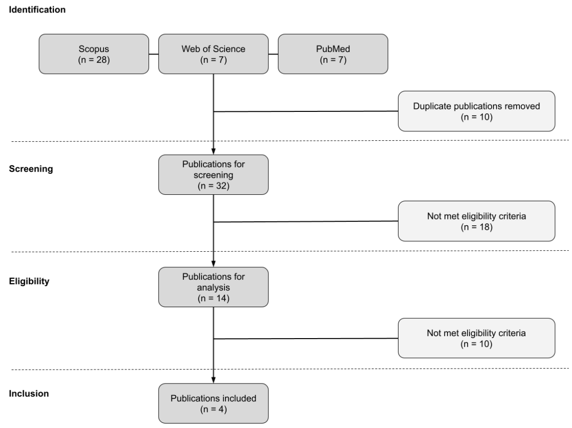

Fig. 1 - Flowchart of the literature review methodology.

During the screening, seven of the eighteen publications removed were review articles. Some characteristics of the four selected publications are shown in Tab 1. The geographical diversity of the studies shows that the need for better technologies for analyzing animal behavior is common to different laboratories around the world. Tab 2 summarizes the objectives and methods proposed by the four selected publications.

Tab. 1 - General information of publications included.

First author	Study location	Journal	Year of Publication
Hatton-Jones, KM [4]	Australia	Computers in Biology and Medicine	2021
Gerós, A [5]	Portugal	Behavior Research Methods	2020
Storchi, R [6]	England	Current Biology	2020
Segalin, C [7]	USA	eLife Neuroscience	2021

Tab. 2 - Summary of technological aspects of publications included.

First author	Problem and objectives	Solution proposed	Technologies used
Hatton-Jones, KM [4]	Detection and classification of behaviors in mice in the Open Field Test (OFT).	Computer vision system based on Deep Neural Networks (DNN).	YOLOv3 DNN model.
Gerós, A [5]	Automatic detection and classification of behaviors of rats in the OFT and Elevated Plus	Computer vision system with modules for video acquisition, annotation and processing.	Microsoft Kinect v2 for RGB-D video acquisition and SVM (Support Vector Machine) as the behavior

	Maze (EPM).		classifier algorithm.
Storchi, R [6]	Detection and 3D reconstruction of mouse postures in the OFT.	Supervised model for 3D reconstruction of animal postures based on coordinates.	Statistical Shape Model (SSM) and multiple cameras setup.
Segalin, C [7]	Automatic detection and classification of mice behavior.	Machine learning data pipline.	DNN and HMM (Hidden Markov Models).

The main similarity between the four studies is the use of rodents as their research animal models. Although there are significant differences between mice and rats, computational methods can be more flexible to generalize the analysis of behaviour between different species. On the other hand, the environment in which the animal is inserted, or the background of the object of interest, is important for the development of a more specific or generalist model. Three of the studies use the OFT. This test has a standardized construction, although there may be variations. Therefore, an algorithm built for this test must be able to perform with different videos of the same type.

All the studies use some form of machine learning or computer vision. The classification algorithms are supervised, which even leads to the open availability of the training datasets used in the works by Gerós et. al [5], Storchi et. al [6] and Segalin et. al. [7]. The works by Gerós et. al [5] and Segalin et. al [7] resulted in validated software that is freely available.

4. Discussion

The aim of this paper is to carry out a brief literature review in order to identify which machine learning techniques are being used in the field of computational ethology. The results of the studies have not been statistically evaluated or compared.

Hatton-Jones et. al [4] and Segalin et. al [7] used DNN, including models widely used in other research domains. The YOLOv3 model used by Hatton-Jones et. al [4], for example, has excellent object detection performance. Although it is only capable of classifying exploration behaviors in the OFT, which includes tracking animal locomotion, its application has an impact on behavioral analysis time. Automated methods in ethology tend to be faster than human annotation, as proven by this work. Both studies use similar evaluation metrics, such as mean average precision (mAP). Although these metrics are not relevant if isolated from other forms of analysis, one of the papers obtained a mAP of over 99% [4].

Gerós et. al [5] also show that data acquisition is extremely important, as its overall quality has an impact on the final result of a machine learning model. Using depth cameras, which are now common even on smartphones, it is possible to extract more information from the three-dimensional aspects of image frames. This information is important for making it plausible to classify more refined animal behaviors, such as grooming. In this way, it would be possible to overcome the limitation of the work by Hatton-Jones et. al [4]. Storchi et. al [6] do not describe the use of a more well-known machine learning approach, in contrast to the other works. For the 3D reconstruction of animal postures, a specific statistical model for the problem was developed, which may limit its reproducibility.

The level of generalization between different samples of video frames from the same test in itself is extremely difficult to achieve and depends on the quality and quantity of the training data, in the case of supervised algorithms. Therefore, a future prospect is the development of more agnostic methods, in the sense of being generalist in terms of the type of video being analyzed. These methods should also dispense with the need for manual annotation of training data, a crucial but often time-consuming step.

It is notable that more studies could have been identified for further analysis. In part, this can be explained by the fact that the term "computational ethology" is too broad for various animal species, including those outside the laboratory research environment, which were not considered for this work. Indeed, a quick search for the term "computational ethology" on Google Scholar reveals at least 608 results. Also noteworthy is the fact that not all papers that apply computer vision and machine learning techniques use the term ethology in their publications. Efforts towards a more standardized terminology in the area are necessary.

Finally, a possible shortcoming identified in these studies is the lack of transparency in the models. In fact, machine learning algorithms such as DNN and SVM are intrinsically very good in terms of accuracy, but have low interpretability [8]. Because of this, DNN are often referred to as black-box algorithm. To resolve this issue, the use of Explainable AI (XAI) approaches may be one way forward. As researchers increasingly automate their behavioral analysis tasks, automated methods need to be reliable, producing statistically relevant answers.

5. Conclusions

Machine learning models, especially deep learning with DNN, have proven to be state-of-the-art in computational ethology. The use of these algorithms allows for quick and objective analysis of videos of behavioral tests with animal models. In themselves, these are advantages over the traditional style of ethological analysis, which uses analog means and requires manual annotation by an expert observer.

In the future, new unsupervised approaches should be able to predict behavior and exclude the need for annotated data for training. Finally, the association of computational video analysis with other physiological signals should lead to advances in basic research with animal models.

6. Acknowledgement

My special thanks go to all the collaborators in the Neuropsychopharmacology laboratory at Universidade Federal de Ciências da Saúde de Porto Alegre, Brazil, who gave me the opportunity to learn about animal behavior analysis and opened doors for the development of new ideas.

I would also like to thank everyone involved in UNIGOU Scientific Training, not only for the knowledge gained through high-quality content, but also for their support and attention.

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