Animal Health Informatics: Towards a Generic Framework for Automatic Behavior Analysis
Position Paper

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Keywords: Animal Behavior, Animal Welfare, Veterinary Informatics, Computer Vision, Deep Learning.

Abstract: The field of veterinary healthcare informatics is still in its infancy, and state of the art solutions from human healthcare are not easily adapted. IoT and wearable technologies may be bringing a wind of change, as large amounts of health data of animals are now being produced. It makes this a timely moment to initiate a discussion on the possibilities for cross-fertilization between the worlds of human and animal health informatics. In this position paper we report on an ongoing project developing a framework for automatic video-based analysis of animal behavior and describe its concrete application for decision support of behavioral veterinarians. The framework is generic, allowing for reuse across species and different analytical tasks. We further discuss the possibilities for cross-fertilization between human and animal behavior analysis in the context of health informatics.

1 INTRODUCTION

The notion of veterinary informatics was coined by Talbot (Talbot, 1991), surveying the many applications of medical informatics in the veterinary profession. Such applications have explored messaging standards, terminology lists, and standardized diagnosis lists (Santamaria and Zimmerman, 2011), as well as applications of bioinformatics techniques to the veterinarian domain (Sujatha et al., 2018). Yet more than two decades after Talbot, the field is still in its infancy (Smith-Akin et al., 2007; Alpi, 2009) and state of the art methodologies used in human healthcare informatics are neither easily adaptable, nor easily adopted by veterinarians.

Recent technological advances in IoT and big data may bring the wind of change to the world of animal health informatics. These technologies have started to transform the living conditions of farming animals, bringing to public attention also issues of food quality and sustainability. The pet market is also catching up[1] on the hype of wearable devices, with a variety of activity and fitness trackers for pets which include sensors that can measure activity, sleep and vital signs of pets. There are initiatives such as the PetCommunity Blockchain, promoted by Petpace, aiming to create a global network of interconnected health pet data, to be produced and consumed by pets, owners, veterinarians, and service providers. Thus animals have started to produce significant amounts of health data. This holds a great promise for a cross-fertilization between the worlds of human and animal health informatics.

Tools developed by informatics are useful not only for veterinary science, but also for animal welfare – especially for automatic assessment of behavior. Animal welfare science seeks to handle welfare issues raised by the keeping and use of animals. It defines different welfare parameters with regard to physiological state, affective state, and natural living state (Broom, 1996; Fraser, 2009). Behavior analysis is an important tool in the assessment of animal welfare used for the assessment of pain, injury and disease. Behaviour is also of crucial importance in gauging what animals want (Zamansky et al., 2017), most obviously in the use of choice and preference tests, but also through other methods that are particularly suitable for on-farm welfare assessment (Dawkins, 2004).

Thus behavior analysis and assessment is an integral part of animal health and welfare. There are

[1] The pet-wearables market is expected to grow at a CAGR of 13.5% before 2025, with exponentially growing demand from Asia following initial popularity in the West.

Kaplun, D., Sinitca, A., Zamansky, A., Blauer-Elsner, S., Plazner, M., Fux, A. and van der Linden, D.
Animal Health Informatics: Towards a Generic Framework for Automatic Behavior Analysis Position Paper.
DOI: 10.5220/0007566504360441
In *Proceedings of the 12th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2019)*, pages 436-441
ISBN: 978-989-758-353-7

voices calling for objectivization of methods for assessing and analyzing behavior. As Karen Overall noted in (Overall, 2014), “A review of behavioral data over the past decade supports a serious shift to crisper definitions of terms and quantifiable assessment of behaviors. Veterinary behavior and veterinary behavioral medicine are coming later to this approach, but the change is welcome.”

Informatics can have a great impact on such objectivization, supporting behavior analysis in a more quantifiable and objective way, both in terms of precision and in terms of volumes of processable data. Indeed, automatic tracking systems based on video analysis are widely used for different species of animals, such as wild animals (Burghardt and Ćalić, 2006), pigs (Ahrendt et al., 2011; Tillett et al., 1997), poultry (Sergeant et al., 1998), insects (Noldus et al., 2002), and many more. Well-developed systems for rat and mice behavior recognition such as Ethovision (Van de Weerd et al., 2001) and Laboras (Spink et al., 2001) are widely employed in behavioral research.

While companion animals such as dogs are the most frequently addressed species in animal health research and practice, until now very few works addressed automated analysis of their behavior. One approach, which has been gaining increasing interest with the development of commercial smart collars and trackers, is using wearable sensors such as accelerometers and gyroscopes to recognize behaviors and analyze motion. Several such systems have been proposed (Gerencsér et al., 2013; Brugarolas et al., 2013), but currently only basic behaviors can be recognized with reasonable accuracy. Commercial trackers, such as FitBark and Petpace, may offer better accuracy, but are yet to be scientifically validated to be applied in health related settings.

In this paper we describe a *video-based* approach to automatic analysis of animal behavior. Our project started out focusing on companion animals, but expanded into a *generic* approach, which can be used across species, as well as across health related analysis tasks. Another feature of our approach its low cost and simplicity, so that it can be easily applied in different practical health related settings, and e.g., can be integrated into clinician’s workflow. It is low cost and simple to use by working with data obtained from the most basic affordable equipment, i.e., a cheap web camera that requires no special installation. Our approach consists of two layers: (i) a computer vision layer, which performs automatic tracking of the animal by applying state-of-the-art machine learning techniques, and thus is easily trained on different species of animals in different settings, and (ii) a sense making layer, which interprets the information extracted by the computer vision layer according to the health related task at hand. This separation of concerns facilitates the genericity of our approach.

In the rest of this paper we describe our approach and its concrete applications in animal health informatics. We further highlight the need for generic and simple solutions for animal health informatics, and call for cross-fertilization between animal and human health informatics.

2 THE BLYZER FRAMEWORK AND ITS APPLICATIONS

The current study is part of an ongoing research project, which is a collaboration between the Tech4Animals Lab[2] at the University of Haifa and the AI lab at St. Petersburg Electrotechnical University ”LETI”. This project aims at developing automatic tools for animal behavior analysis using state-of-the-art machine learning techniques. We start by describing the Blyzer approach, and then present two concrete applications in different settings related to animal health.

The Blyzer (Behavior analyzer) approach provides a generic solution for automatic behavior analysis. By ‘generic’ we mean that it can be easily reused across species and environments, and across different analysis tasks, as we explain below.

Figure 1 provides an overview of the approach. The Blyzer architecture consists of two different modules. The computer vision module tracks the animal in its chosen environment, producing spatio-temporal data (location of animal in each frame, speed, orientation, etc.). The sense making module uses the extracted spatio-temporal data for producing the chosen analysis. To calibrate the computer vision module, sufficient amount of video footage of the chosen species in the chosen environment needs to be recorded. The frames are manually tagged, and machine learning techniques are applied to produce an appropriate classifier for the computer vision module. To adapt the sense making module to the needs of the user, the analysis task needs to be formulated in precise terms.

The results can then be shown to the user by creating an appropriate interface. We describe concrete applications of the framework in the context of animal health in the following section.

[2]See: http://www.tech4animals.org

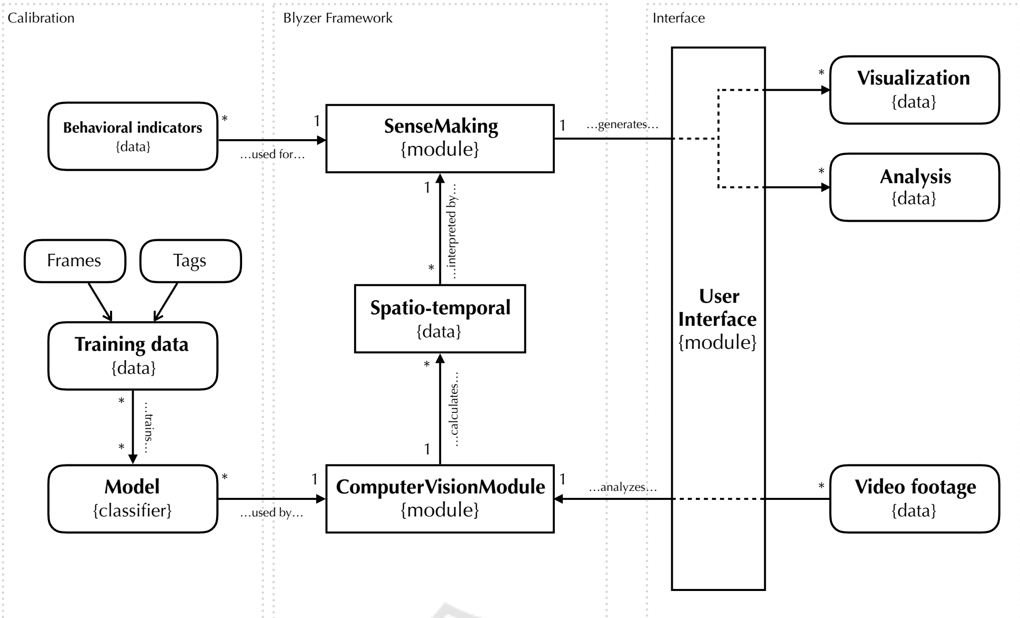

Figure 1: Blyzer architecture.

3 DECISION SUPPORT FOR BEHAVIORAL VETERINARIANS

Behavioral disorders of domestic dogs (*Canis Familiaris*) such as aggressive behavior, lack of self-control and anxiety are a major threat for the well-being of companion dogs and their owners, leading to dogs' relinquishment to shelters, or preventing shelter dogs from being adopted, eventually leading to their euthanasia (Winslow et al., 2018; Scarlett et al., 2002; Sherman and Serpell, 2008). One behavioral problem frequently encountered in veterinary behavior practice is dogs' hyperactive behavior. Such dogs are impulsive, restless and inattentive, are difficult to train and may be dangerous to children and adults during play due to lack of control of their bites. The increasing interest in this disorder is reinforced by recent evidence that the domestic dog is an adequate model for the human Attention Deficit Hyperactive Disorder (ADHD) (Hoppe et al., 2017; Lit et al., 2010).

Diagnosis and treatment of behavioral problems require special expertise in veterinary behavior. A consultation with veterinary behaviorist lasts longer than a regular checkup and is usually held according to the following protocol. The vet starts with discussing the dog's behavioral issues and main complaints. He will then gather information from the owner on adoption history, systematic behaviour work up (eating, drinking, sleeping, playing, exploring, agonistic, housetraining, somatosensory, phobias, sexual), attachment quality, previous training history and methods, living conditions (garden access, daily exercise: type and length). Depending on his diagnosis hypothesis and after ralizing the physical exam, he might want to rule out some medical causes. At this stage the dog may undergo complementary tests (blood and urine tests, X-ray, MRI, etc). The direct observation is done by the vet during this discussion with the owner. That's usually the time of the consultation when the behavioral diagnosis is established.

The classification of pathological disorders and treatment decisions of a behavior specialist veterinarian are usually done on the basis of (i) observation of the dog during consultation, and (ii) owners' self-reporting. Concerning diagnoses, there is no current consensus in the behavior community and several approaches exist. On one hand, most of them use a descriptive approach, centered on describing the symptoms like "storm phobia, food related aggression, anxiety" but no pathology name is established gathering the symptoms (Overall et al., 1997). On the other end, the French Veterinary Psychiatry based on the nosography established by Pageat uses the same descriptive symptoms but gathers them into pathologies (e.g., deprivation syndrome) (Pageat, 1998). Further discussion of these approaches is beyond the scope of this paper. While in our evaluation we used cases diagnosed using the French approach, our automated approach is independent of the underlying behavioral approach.

The final aim of a behavioral consultation is establishing a treatment plan, whose possibile options include e.g., environment modification, behavior modification, and medication[3], or some combination of these options. To establish a treatment plan, behavior assessment needs to be performed.

To quantify behavior assessment, several scales and questionnaires have been developed and validated, such as the C-BARQ (Hsu and Serpell, 2003) or the dog ADHD rating scale (Vas et al., 2007). However, these scales are owner administered, and thus are subject to non-objectivity and inaccuracy (i.e., there is evidence that owners may misinterpret the behavior of their pets (Mariti et al., 2012)). The animal behavior research community has thus been calling for further "objectivization" of behavioral assessment (Overall, 2014).

In our ongoing project, we aim to support behavioral veterinarian decision making, providing objective assessment tools for behavioral problems such as ADHD-like behavior to be used during consultation. For this particular disorder, for instance, we currently aim to measure the degree of 'erratic' movement of the dog around the consultation room, which indicates the level of self-control exhibited by the dog, which in many cases appears to be correlated with ADHD-like behavior (at least in the pure cases without comorbidities).

The system based on the Blyzer framework is currently deployed in three behavioral clinics in Israel and France. Using a simple camera attached to the consultation room ceiling, the vet records the dog. The recorded video, along with dog's diagnostic data, obtained from the owner report and additional dog's physical exam, is stored in a database. The veterinarian can compare the different parameters which measure, e.g., how erratic the movement is (indicating the level of self control), between different dogs, and between different visit of the same dog (e.g., before and after receiving medical treatment for ADHD-like behavior).

In this particular case, the Blyzer framework is instantiated as follows. The classifier model for dog detection was trained on video footage (see Fig. 2) recoded in the clinics. The model was developed using TensorFlow Object Detection API faster_rcnn_resnet101, and was trained on around 6000 manually tagged frames. The computer vision module now reaches a very high accuracy (above 90%), producing a spatio-temporal data in the form of time-series (location of the dog per frame). The sense making module currently supports visualizing the dog's movement, computing its different parameters and characteristics helpful for quantifying the amount of "hyperactive" movement. Figures 3 and 4 demonstrate a visualization of the movement of two dogs: normal and pathologically hyperactive during the first 3 mins of visiting the clinic.

Figure 2: Computer Vision Module tracking the dog in a clinic.

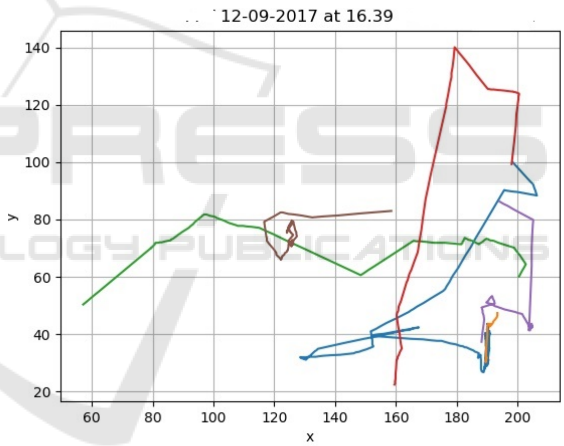

Figure 3: movement of a normal dog (first 3 mins).

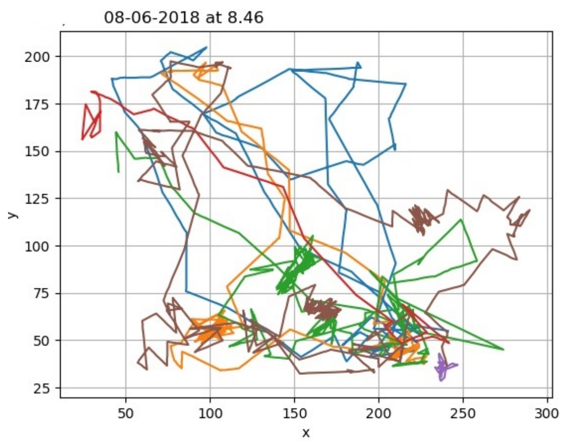

Figure 4: movement of a hyperactive dog (first 3 mins).

[3] In some cases, surgical procedures, such as castration, can be part of the management plan.

A different example of an analysis task is provided in our work (Zamansky et al., 2018), where similar video analysis of the movement of dogs diagnosed with anxiety when interacting with a moving toy was analyzed, showing that anxious dogs were more inhibited and moved less when interacting with the toy.

4 DISCUSSION AND FUTURE RESEARCH

We have described our approach aiming at genericity and simplicity of use for behavior analysis for multiple species and health settings. We hope that these ideas can facilitate the growth of animal health informatics and promote digitalization in veterinary science and animal welfare. We envision many different applications for the Blyzer framework, and are currently working in several its extensions, expanding the scope of animal health informatics to the domain of animal welfare.

Animal welfare is commonly centered around three broad objectives: (1) to ensure good physical health and functioning of animals, (2) to minimize unpleasant “affective states” (pain, fear, etc.) and to allow animals normal pleasures, and (3) to allow animals to develop and live in ways that are natural for the species (Fraser, 2009). According to Dawkins, behaviour analysis plays a major role in these objectives: “It is used in the clinical and pre-clinical assessment of pain, injury and disease, and potentially could have an even greater role, particularly if used in conjunction with new technology. It is also of crucial importance in gauging what animals want, most obviously in the use of choice and preference tests, but also through other methods that are particularly suitable for on-farm welfare assessment.” (Dawkins, 2004).

Having simple and generic automatic tools for behavior analysis thus has the potential not only to support clinicians in their diagnostic decisions, but also to impact welfare of companion, farm and zoo animals. In his keynote talk at the Animal-Computer Interaction Conference in 2007, Donald Broom, the founding father of animal welfare science encouraged informatics to offer technological solutions to pressing problems of welfare of animals, keeping which for production, work and entertainment continues to be a norm in modern society. We therefore suggest to expand the notion of veterinary informatics, coining the term ‘animal welfare informatics’. To give a concrete example, one extension of the Blyzer framework we are currently working on involves analysis of the sleep quality of sheltered animals and animals kept in zoo environments to improve their physiological and psychological wellbeing.

The development of such tools could also push the boundaries of human health informatics. While analysis of video is one of the main research methods in studying animal behavior (see, e.g., (Palestrini et al., 2010; Cannas et al., 2014)), it has some parallels to the use of video in human healthcare contexts (see, e.g., (Stronach and Wetherby, 2014; Konofal et al., 2001)), which may provide some hints towards the possible generalizability of some results obtained in veterinary informatics to human context.

Moreover, some behavioral disorders of animals have strong connections to similar disorders in people, and data analysis performed in animal healthcare informatics may inform and complement human healthcare research. For instance, the domestic dog has been suggested as a model to investigate human behavioral disorders such as the Attention Deficit Hyperactive Disorder (ADHD) (Hoppe et al., 2017; Lit et al., 2010).

To summarize, state-of-the-art machine learning techniques make it possible to easily develop automatic tools for behavior analysis, which can greatly impact animal health informatics. It is our hope that this paper will also initiate a discussion on possible cross-fertilization opportunities between animal and human informatics with respect to automatic behavior analysis.

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