Video Deep Tagging and Data Archiving in the Comparative Mind Database

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ABSTRACT
In this paper we describe our efforts towards a Comparative Mind Database and discuss an available component, the video sharing and deep tagging system. We present the "Comparative Cognition" project of which the database component is a module, and present general discussions of data archiving and processing in various scientific contexts, from astrophysics to animal behaviour. Afterwards, we turn to the discussion of the developing system and various aspects of its benefits. Finally, we describe the fundamental features of the video system and its advanced, cutting edge functionalities to support the study of animal behaviour.

Author Keywords
Comparative cognition, comparative mind database, data archiving and sharing, video archive, deep tagging

INTRODUCTION
The Comparative Mind Database (www.cmdbase.org) is an activity of the project „The Evolution of Social Cognition: Comparisons and integration across a wide range of human and non-human animal species", an ESF Research Networking Program (www.compcog.org). The general objective of the parent project is to develop "real" comparative cognition across a wide range of vertebrate and invertebrate species (including humans) with a coherent theoretical background, unified terminology and standard methods, and to make it transparent for and integrated with other fields, like social sciences, genetics, physiology, animal welfare, robotics, and so on. The program brings together 28 European laboratories from 11 countries, and runs for 5 years since May 2008.

Despite the existence of a large body of fragmented knowledge, we do not currently understand human and animal cognition. What constitutes the animal that we talk about, i.e. how can it be conceptualized? What are the terms to be used, and how they are backed up in the various disciplines that are relevant for the experimental and theoretical study of animal and human behaviour? How can different species and different experiments be compared with, if they measure different things (or even if they claim to measure the same thing)? What are justifiable conceptual and experimental methods that can support reproducibility, scalability, and generalizability? We believe these questions are strongly interrelated with what can be broadly called *documentation* and *conceptualization*.

The Comparative Mind Database is a module of the CompCog project that supports the above inquiry using innovative, advanced information technologies and methods from philosophy of science, statistics, experimental design and data/text mining. Its envisioned components include: Web2.0 style computational tools and methods for data acquisition and description, procedures for data and text mining for conceptual analysis, specific ontologies for animal cognition, integrated tools for the design and analysis of experiments (DoE), and work towards the standards of experiments, their communication and evaluation.

DATA ARCHIVING AND PROCESSING
The public archiving and sharing of data is becoming almost ubiquitous. Since the recent declaration of various platform statements, many journals have adopted an archiving and sharing policy. The platform statements in question range from the announcement of the PetaByte age [1, 4] through the Jerusalem declaration [3] to the notion of Web Science [7]. The essence of the Jerusalem declaration is: "public money – public data" for research, and this

formulates a very natural requirement for data sharing and archiving.

Many of the above topics point towards the usefulness of comprehensive, integrated databases. Databases can come in various formats from the simple deposits to complex systems that use suggestive tools for the acquisition, handling and analysis of data. The database could be also suggestive as a unified documentation, synthesis and repository tool for much of existing information. Such database initiatives include the "virtual observatory" of astrophysics. In astrophysics, a prior submission of all data before publication is required today [6, 10]: The virtual observatory enables a new way of doing astronomy, moving from an era of observations of small, carefully selected samples of objects to the use of multi-measurement data for millions, or billions of objects. Such datasets allow researchers to discover subtle but significant patterns in statistically rich and unbiased databases, and to understand complex astrophysical systems through the comparison of data to numerical simulations. The virtual observatory provides simultaneous access to multiple archives and advanced visualization and statistical analysis tools.

Recently, evolution and ecology journals also move towards a Journal Data Archiving Policy [9] and at this time the journal Animal Cognition is considering the use of a similar practice (Czeschlik, personal communication, 2010). These policies – similar in vain to those in use in astrophysics since almost a decade – put strict conditions on publications by requiring the publication (i.e. public archiving) of all relevant data.

THE COMPARATIVE MIND DATABASE INITIATIVE

The development of the Comparative Mind Database capitalizes on these prior approaches and results, and extends them for the specific purpose of the study of animal behaviour. Databasing animal behaviour poses new kinds of challenges, however. Comparative cognition aims at reconstructing the evolutionary history of various cognitive skills via investigating which animal species demonstrate or lack them. Such species comparisons require comparable methods utilized by different research labs keeping and/or working with subjects of one or few species. For greater importance even subtle variations in observational and experimental methods can differentially influence the animals in study as well as the interpretation of data. The current form of a paper's method section and the supplementary demo videos hardly provide enough data for the reproduction of studies on animal cognition. These challenges can be overcome by developing a suitable system for animal cognition related data archiving and sharing.

Over the last years there have been a few attempts to develop database(s) for the behavioural sciences that do not seem to have achieved their aims. One may argue that the fundamental problem lies in the complexity of the structure under study. But also, in contrast to other fields, like astrophysics or genetics where complexity might be a similar issue, the behavioural sciences have not developed a useful definition of "data". A recent review showed that for many researchers even the definition of the term "behaviour" was quite elusive [5]. Following their survey, these authors are inclined to define behaviour *as „the internally coordinated responses (actions or inactions) of whole living organisms (individuals or groups) to internal and/or external stimuli, excluding responses more easily understood as developmental changes"*. Importantly, however, this definition avoids referring to those physical (visual, acoustic etc.) attributes of an "action" that should be "captured" for such a database, that is, for this definition the behaviour should be "describable" in some general ways.

Importantly, in contrast to astrophysics, genetics and cosmology, most of the behaviour data are still obtained more or less by direct human intervention (especially in the animal and human cognition domain), which is deficient in "objectivity". In contrast, physical parameters measured by specifically designed (and validated) equipments used by a scientific community (e.g. Hubble space telescope) or the units of the genetic code provide a clear case for data banking because the data have been collected reproducibly by standardised (non-human) instruments.

However, the behavioural sciences cannot avoid moving into the age of data banking. This process has already started. For example, software technology allows for automated collection of some specific behavioural data (movement in space, simple interaction with objects, etc.) in simple environments for laboratory species (e.g. EthoVision - Noldus), wild living animals can be equipped with GPS sensors, etc., but especially in the field of cognition most data are collected "by hand" utilising a diverse array of experimental approaches. Importantly, modern technologies emerge offering more objective collection of such behavioural data. For example, "looking time" is often used as an index for different cognitive processes. Traditionally, the human experimenter (observer) noted the duration of a particular head orientation by hand held timers, or more recently, by counting video frames. However, in some particular cases it is now possible to use eye tracking devices to obtain observer-independent data on "looking". In an ideal situation the change from a human-based coding to a machine based data collection would make such data more useful for data banking.

Despite such advances in technology objective, "en mass" data recording from freely moving, "behaving" systems will not be achieved in the near future. Nevertheless, in this time there is a possibility for making advances in areas in which some basic requirements for data banking are in place. Thus we suggest that a Comparative Mind Database (CMD) could have two important contributions for the behavioural sciences.

The Weak Form of CMD

The idea of weak CMD is based on the experience that despite sometimes lengthy descriptive method sections, more or less clear definitions of behaviour, ad hoc provided video files, and intra- and inter-observer reliability, the "objective" definition of the data is inadequate for data banking. The weak form of CMD can be seen as providing a suitable framework for collecting and sharing basic data in forms specific to the behavioural sciences. It could be useful as an aid (or eventually an obligatory tool) for publishing behavioural data in scientific journals, to teach students how to plan experiments, to share data and methods with fellow scientists, and to contribute to a common data base. The utilisation of video data together with tools that help to describe the "behaviour" could canalise data collection, eventually leading to data which have been collected in very similar ways.

The Strong Form of CMD

The strong form of CMD is aimed at providing a storage space, definitions and ways of sharing, that is, bringing behavioural data from different sources onto a common platform, providing interlinking and common reference. Note that the strong form of CMD is useless until the weak form of CMD is realized, because data from under-defined data sources are worse than no data at all.

SOLUTIONS FOR A COMPARATIVE MIND DATABASE

We started to realize these plans by working on a prototype of the CMD. Besides adopting existing technologies found in different domains mentioned earlier, our suggested new solutions include an innovative copyright handling, integration, raw/select data archiving, and online/offline processing. One of the notorious issues is copyright handling. The current Journal Data Archiving Policy foresees an embargo prior to publication (where the data is uploaded but not shared, and a moratorium of one year after publication during which the data owner has priority of publication using secondary analysis). This is an important step but may not be sufficient in all cases – our proposed system offers different copyright formats selectable by the owner at upload time.

Another recurrent issue is integration: many data archives are scattered and put their data in a different context than it was produced or processed. This raises several questions from the attractiveness to the usefulness of such archives. We are attempting to overcome this issue by endeavouring to develop a framework for the uniform handling of experiments (form design to evaluation and theoretically to paper writing), and the uses of advanced methodological tools for data analysis such as MEME (developed by one of our contributors, Gulyas 2010, [2, 8]). Usually, by "data" something distilled is meant – most archiving initiatives do not concern "raw data" in the form of lab notebooks or video recordings. However, for animal behaviour raw data is also of significance, both for secondary analysis and quality control. We are treating raw and processed data (below: video footage and edited shots) in the same way, interlinked with pointers and tags.

Finally (and also related to the copyright issue, but also to data safety and availability), many researchers might be reluctant to put their current experiments into the public domain, and especially to use Web 2 tools for strategic mass storage as the only form of archiving. As a solution to this, and handled together with the raw/edit data policy, our tools will be available online as well as in an offline version (with the online version providing more "goodies" such as integrated data processing and "paper writing" tools). This way the scientist can use the system in her laboratory as well as in the public domain and turn to the latter only at paper writing time, or for edited data only, while keeping (i.e. archiving) raw data in her local system. During its five years of operation, the CompCog/CMD project endeavours to develop a unified encompassing framework and toolkit for such data preparation, handling, archiving and processing task, for raw data (such as video footage) and processed data alike. The prototype CMD is focused on video representations, and is available in the form of a fully functional alpha version (announced in May 2010).

VIDEO ARCHIVING, SHARING AND DEEP TAGGING

The CMD video platform is a community platform that offers several different functions. These functions include: registration, video upload, video editing (in particular, tagging, annotation and deep tagging), timeline control, video (as well as annotation) search and video playback (in various sizes). It takes the form of a video sharing system on a backbone similar to that of YouTube. The system is available at www.cmdbase.org.

Video tagging is a common technique to assign metadata (such as author, title and time information) to videos in an archive. Deep tagging is a recent development that extends advanced tagging (i.e. the use of tags, bookmarks, and other descriptive elements, including attachments of various kinds) to the temporal domain, by permitting the data owner to enter the "depth" of the video. Deep tagging involves the use of temporal tags and a timeline that positions these tags over the duration of the video. Deep tagging became widely known in 2007 and is now available in various commercial products such as Momindum (www.momindum.com) (however, they are costly and not open source, hence not scalable and extendable, nor tailored to scientific needs).

Video annotation goes even one step beyond deep tagging. The idea is to allow users to place marks, even drawings (including simple shapes, text, and hand drawing/writing to frames or intervals of the video. The system features an interval editor that configures each tag and annotation in time: the minimum duration is 1 second; the maximum is the video's entire playtime. In edit mode, the timeline shows the timing and the overlay of different instances and the layers of all tags and annotations. Video annotation may have uses in different domains but currently few tools exist that can support it. In animal behaviour studies, together

Figure 1. Editing and deep tagging in the CMD system.

with deep tagging, video annotation may have a key role in the future for the identification (and documentation) of various behaviour elements, their relation to each other and the experimental design, and the mark-up of experimental settings, which includes the identification of various environmental cues. Our realized tool has a flexible management system that allows various policies for both tagging and annotation: from owner-only to general access. Currently no other available system supports the variety of these functions, ranging from archiving and sharing to deep tagging and video annotation. The tool is open source and freely extendable.

ANNOTATION AND DEEP TAGGING: AN EXAMPLE

The system has three main pages: namely, the main portal page, the editor and the player. A toy example is shown below for the use of the editor page to create video markup in an imitation experiment (found in the database at www.cmdbase.org under the name MouthFull.mpg). The editor page shows the video and a timeline where a relocatable line marks a current moment. Positioning the line to a desired moment, graphical annotations (here at 21. sec, an ellipse and two text boxes) can highlight critical parts of the picture or provide short written explanations. Their temporal duration is also shown in the timeline and can be controlled by dragging their markers' ends. Tags and bookmarks (at the upper right panel) support navigation on the video: critical moments can be marked and jumped on with one single click. In the example on Fig. 1, the animal is captured in the position where, in contrast to the preferred paw action of dogs, she is demonstrating an unpreferred paw action to manipulate an apparatus, which is justified by her mouth being occupied by a ball she carries during the demonstration. The experiment investigates whether observer dogs copy the model's paw action after watching 10 demonstrations. Rather subtle behaviours need to be noticed during the 8 test trials. In contrast with demo videos typically used in behavioural sciences, the new system can offer footages where all methodological details of the experiments can be followed in the archived experimental video, and at the same time tagging the video can highlight the critical but subtle events in the animals' behaviour (see red arrows and text boxes at moments 0:06:02, 0:06:53 and 0:06:58). Attachments such as a ppt slide or a pdf document can also be associated with a given frame using the bottom right panel. (Attachment links are shown in the player and until a new attachment comes up.) They can either provide further details missing from the video (such as structure of the apparatus on the first ppt slide in this example (0:00:12)) or can directly connect the behaviour observed and the graphs presented in the publication PDF (e.g. 0:06:02).

CONCLUSION

We presented general discussions and ongoing work towards a comprehensive, domain specific database for comparative animal cognition with archiving, sharing and data processing capabilities and we presented an example component, a fully functional video sharing, annotation and deep tagging system, available in an alpha version.

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