Universität Konstanz

Centre for the Advanced Study of Collective Behaviour

Template for MEDIUM PROJECT Proposals

Medium Project Proposal Template EXC2117			
Project Title	A software framework for multisensory environments		
Total funds requested	80000	**Project Duration**	**1 year**
Names of involved researchers	**Primary researcher: Hemal Naik.** **Collaborators: Prof. Bastian Goldluecke, Prof. Oliver Deussen, Prof. Britta Renner, Prof. Iain Couzin, Dr. Mate Nagy (external).**		

Are you working on a project currently funded by the Cluster of Excellence? YES/NO?

NO

Do you intend hiring for a position within the proposed research project? YES/NO

Yes, HiWi Student.

Please describe the project in detail (2-3 pages) addressing the following points:

- **research question, objectives, and positioning within the CASCB**
- **interdisciplinarity and novelty of concept and methodology**
- **work program with timeline**
- **budget justification and plan**
- **if applicable: list of collaboration partners**
- **if applicable: use of existing or planned research and information infrastructures**

Please label figures such that they can be understood on their own.

NOTE: the summary must be understandable to non-specialist reviewers and must address the general funding criteria of *innovation; relevance to the cluster; interdisciplinarity.*

The purpose of this project is to develop of a software framework that will allow effective use of experimental facilities with multiple sensors e.g. imaging barn. The framework will standardize the process of synchronized data collection, data sharing (formats) and data manipulation (processing). Such standardisation will promote collaborative development and support technology or methods transfer between different facilities i.e. Barn, Imaging Hangar, human tracking facility at Psychology Dept.

Motivation:
The main motivation for this project stems from the need for developing a high throughput large scale multimodal setup for conducting collective behaviour experiments. A typical collective behaviour experiments involves measurement of behaviour patterns (e.g. movements, vocal calls, postures) of multiple individuals for a long duration. The measured entities and the duration of the experiment vary based on the requirement of the experiments. Consequently, the technology required for continuous measurement varies from one experiment to another i.e. microphone for acoustic tracking or optical cameras for visual tracking. The experimental setup also changes based on the study subject e.g. human, birds, etc. Such setups are demanding in terms of space, monetary investment, and technical skills. Scientists responsible for conducting collective behaviour experiments often customize the setup design based on the available resources, study species, and their technical expertise. Ultimately these choices dictate the range of experiments that can be performed. If the ultimate goal is to accommodate a wide range of experimental ideas, it is important to set up a multi-sensory environment in a large space that may allow the measurement of multiple quantities for a group of same or different species. As of now, there are no readily available multi-sensory measurement techniques and therefore setting up such a setup requires customization by merging different measurement technologies.

On one hand, such setups offer a great advantage to researchers from several disciplines as multiple technologies can be deployed simultaneously to collect rich datasets from a wide range of species e.g. insects, birds, mammals. On the other hand, such setups require considerable technical expertise to process and use the data effectively for behaviour analysis. In addition to the setup, equipment management, and calibration of equipment, the users also have to perform post-processing operations on the data obtained from the multisensory modality e.g. data filtering, outlier removal, synchronization, etc. Typically, each modality has its interface, data format, and communication protocol. In such scenarios, it is ideal to have a software framework that facilitates an easy to use communication layer between the scientist and the technology. Additionally, such a framework brings standardization in terms of method development. Lack of such a framework generally leads to duplication of effort as each scientist tries to obtain the data in their preferred format. Fragmented development practices also results in loss of knowledge if there is no standard way of integrating or reusing the newly developed methods for data analysis or processing.

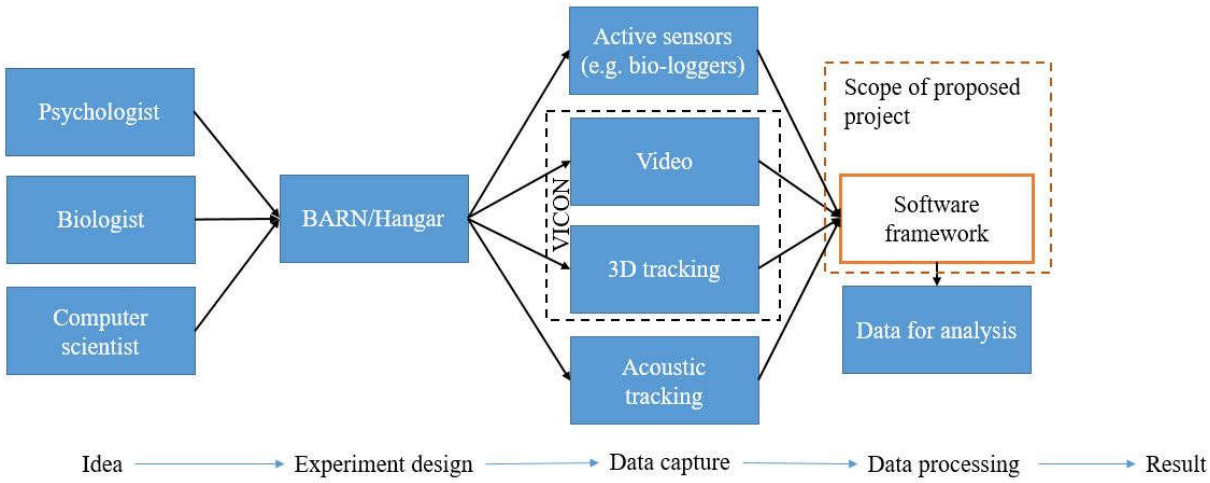

Fig 1. An overview of a typical experimental process from idea to result depicted in the context of the existing setup. The role of the proposed software framework is within the scope of the data processing stage. We argue that proposed development will reduce the time required for processing and provide a platform for rapid prototyping of new ideas.

Currently, there are two such facilities within the cluster where multisensory technologies are used to conduct collective behaviour experiments i.e. Imaging Barn located at MPI-AB and human tracking facility at university of Konstanz. For this proposal, we will focus on the barn because the human tracking facility can be considered as a subset of the setup at the barn. The barn setup consists of VICON motion capture system for 3D optical tracking (30 IR cameras), RGB cameras (6 cameras), and a custom-designed acoustic array (see Fig 1). There is no existing framework that can automatically combine the information from all the three modalities. This presents a big challenge for every new user, especially for those who are not familiar with concepts of programming, computer vision, 2D-3D geometric transformations. There are several additional challenges e.g. high data volume, synchronization (vicon to acoustic), etc. VICON provides a sophisticated interface but the tracking software and data formats are customized for human or robotic applications. The interface has to be customized for tracking animals. Hence, there is a strong need for having framework which can reduce the time required for conducting experiments (see Fig 1).

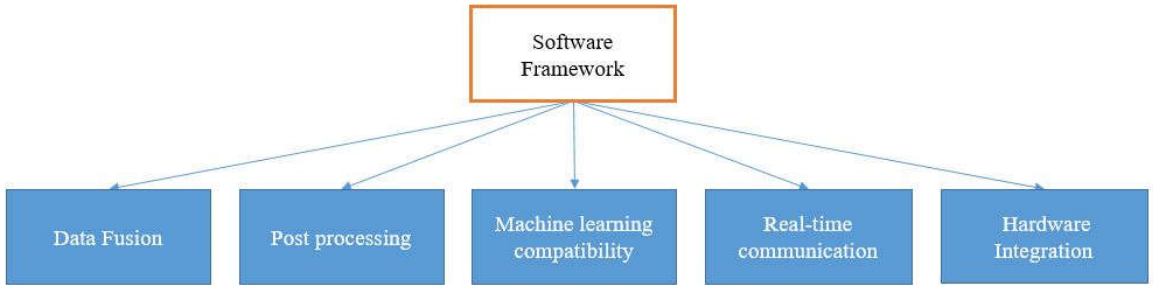

Fig 2. Overview of the main features of the proposed software framework.

Key features of the proposed framework:
Data Fusion: The framework will combine the 3D marker tracking information with video (RGB) data. Currently, this can be done only through VICON proprietary software which prohibits development of the computer vision methods. The framework will also include sync and calibration protocol for data fusion between VICON and acoustic array.

Post-processing: The framework will be designed to allow integration of methods that are designed to process the data from any sensory modality i.e. filtering, outlier rejection, etc. This way knowledge generated (methods or concepts) through different projects will be preserved.

Machine learning compatibility: The framework will include method for annotations on video data using the 3D tracking data e.g. bounding boxes or keypoint annotations. The exported data will be in standard formats such that existing deep learning models (CNN, RNN) can be directly applied. This will also facilitate dataset publication for the machine learning community.

Real-time communication protocol: The framework will include methods to read VICON data streams in real-time for closed-loop experiments. The communication will include sending data to another computer or mobile device over the network. Such a protocol will be useful for AR, VR applications.

Hardware integration: The framework will be designed in a modular way. There will be provision for data integration if additional sensors are added for an experiment e.g. bio-loggers or as an upgrade for the facility e.g. depth camera. However, calibration and synchronization of such devices will depend on the hardware. This project will include a mock implementation for adding an external camera for Augmented Reality application.

Implementation Details and Budget:
Timeline: 12 months
Budget: ~80,000 EUR
Post-doc salary: 74,100 EUR
Hi-wi student salary*: 3000 EUR (200 Hrs @ 14.75 EUR/hr for computer science student)
Computer + Misc* (e.g. web cam or go pro): 2,900 EUR
*costs for salaries or equipment may change.
If additional funding is required it will be secured via small equipment grant in University of Konstanz or the Cluster.

Host Dept.: Dept. of Prof. Iain Couzin. Office space and existing hardware.

Contribution to the cluster:
New ideas: The framework will directly benefit all existing and new users of the facility. It will motivate the rapid prototyping of ideas, which will open further opportunities for experiments and collaborations.

One framework for all facilities: The framework will be generic enough to be deployed at other facilities since they will have similar imaging modalities. This way a standard framework will also facilitate method portability from one setup to another.

How to applications for barn**:** The framework will be developed using several existing datasets (details below). This will serve as a hands-on user guide for scientists using such modalities for the first time. The architecture information will be shared with collaborators in computer science and barn tech in order to maintain the framework for long term use.

Expected outcome:
Framework: code with example applications, documentation, and datasets.
It should be noted that the planned publications (details below) are directly related to the proposed project. The code developed for each dataset will serve as an example code for new users.

List of collaborators:
Computer Science: Prof. Bastian Goldluecke and Prof. Oliver Deussen (Software architecture)
Psychology: Prof. Britta Renner and Harald Schupp (Use cases for psychology experiments)
Biology: Prof. Iain Couzin (Host dept. and will provide use cases for biology)
External Collaborator: Mate Nagy (conceptual input and framework design)

Use of existing research and information infrastructure:

Preliminary framework: I have been part of the team that established the hardware for the facility and I have worked in the barn for more than 2 years during my Ph.D. I have developed a framework that can be considered a preliminary version of the proposed project. The existing version is customized for the bird tracking application and I intend to use this grant to extend the scope of framework and make it more generic.

Dataset: During my Ph.D. I have collected multiple datasets with multiple animal species (i.e. insects, birds, mammals), this will serve as example datasets for development of the framework and example datasets for the future users.

Existing research: I have already published with affiliation to the cluster. I am planning three other publications with collaborators from MPI- Animal Behaviour and the cluster based on work done during my Ph.D. These papers are directly revenant as use cases of the proposed project and will be submitted with the affiliation to the cluster within the timeline of this grant.

Planned Publications:

- Methods paper (In prep): The barn setup as a tool for conducting larger scale collective behaviour experiments with multiple species, Mate Nagy, **Hemal Naik**, Jens Koblitz, Fumihiro Kano, Nora Carlson, Martin Wikelski and Iain Couzin.
- 3D bird posture from monocular view (In prep), **Hemal Naik**, Mate Nagy, Nassir Navab, Iain Couzin.
- Augmented Reality application (In development): Interactive visualization of bird movements in real-time using see-through Head Mounted Display or cell phone, **Hemal Naik**, Goksel Keskin, Iain Couzin, Mate Nagy.
- [**From this project**] A software framework for designing open-loop and closed-loop experiments for collective behaviour studies in a multiple-sensory environment.