An RFID-based Tracking System for Laboratory Mice in a Semi Natural Environment

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Abstract. Knowing the locations and paths of individual mice is important for behavioural analysis of large groups of laboratory mice. Traditional observations are carried out by trained humans who are able to distinguish more than 50 behavioural patterns. A tedious labour limited with respect to observation length. In this paper an RFID (Radio Frequency Identification)-based tracking solution is presented collecting 24h/7days of movement data. Appropriate cage design and antenna placement are discussed and a software solution is presented to facilitate the recording and analysis of mice movements.

1 Introduction

The aim of the project is to detect potential behavioural differences between mice carrying a genetic disposition to develop Alzheimer-like pathology and their wild-type conspecifics under semi natural conditions. Therefore the behaviour of laboratory mice of a transgenic model for Alzheimer's disease (heterozygous TgCRND8 mice and their wild-type littermates) will be characterised in a large indoor semi natural environment (SNE) measuring 1.75 by 1.75 by 2.1 m (L x W x H) (Fig. 1). The SNE contains several floors connected by small bridges and ropes that allow the mice to establish a complex social system comprising different territories.

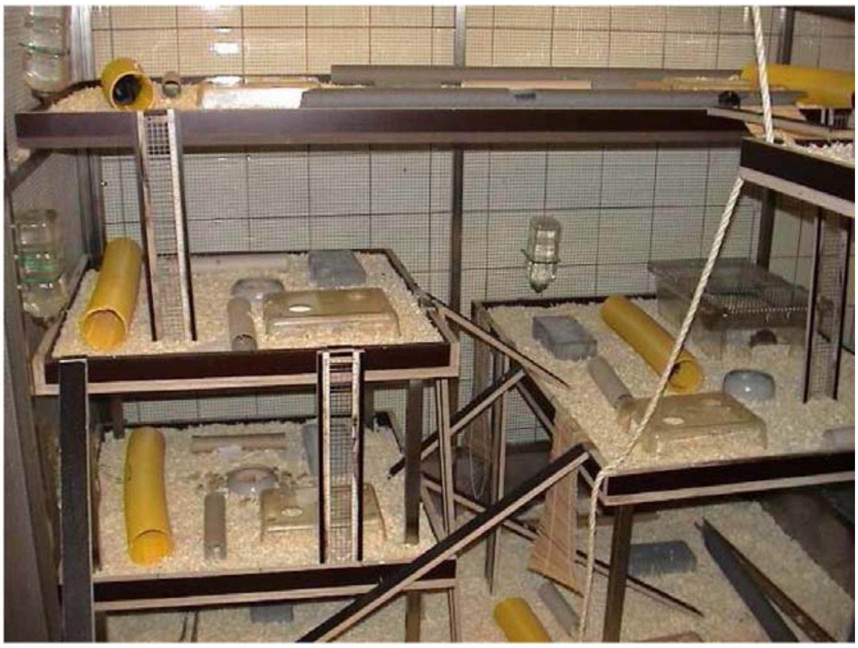

Fig. 1. Semi Natural Environment

Previously, data has been collected manually by observers sitting in front of this complex cage. The observers are thoroughly trained in behavioural biology and can differentiate up to 55 unique behavioural and movement patterns. The population is allowed to grow up to a size of 40 adult mice (plus their offspring), who are individually marked using a colour code scheme on their tails and ears. The resulting data gets analysed statistically to compare mice with different genotypes.

There are, however, disadvantages regarding the manual recording of animal behaviour: The performance of a single human observer varies to some degree constrained by fatigue or mood, and different observers may introduce a specific bias to the recording process [4]. Furthermore, some information (e.g., accurate metric measures) can not be gained by analogue observation of an animal. Human observation is also limited with respect to observation length, making it difficult to gain long-term data (e.g., 24 hour observations). Moreover, data collection during the night-phase is challenging due to the difficulties of identifying colour-marked mice in the dark (it is important to consider that mice are nocturnal animals).

The motivation behind the introduction of an automatic RFID-based tracking system for laboratory mice is to improve and extend human observations. The aim of the project is to establish a system that automatically tracks and analyses positional data of a large number of individual subjects over a long period of time.

In order to integrate the RFID-technology in the SNE some modifications had to be made. The enclosure is equipped with ring antennas placed at strategically chosen spots. The challenge was finding a hardware setup and a cage design which allow to collect consistent data and retain the semi natural character of the cage.

2 Related Work

Different tracking solutions for certain animals already exist. For example, the movement behaviour of Antarctic fur seals is observed by satellite transmitters. Three satellites were used providing a positional accuracy of 150 m to determinate the tracks of the animals [1]. Cows are tracked in their barn using radar technology. Transmitters are fixed at the neckband of the cows, allowing a 2D localisation with an accuracy of 25 cm [5]. These tracking techniques do not fit the requirements for indoor mice tracking. GPS (Global Positioning System) is inappropriate for indoor tracking because of lacking visibility of satellites. The radar technique is not useful because mice cannot wear large transponders. Both technologies also fail with regard to the accuracy requirements for the described project.

The RFID technology for the tracking of the mice is chosen because the passive transponders are very small and therefore easy to inject into the mice. The installation of the antennas in the SNE is possible and accurate positional data can be achieved.

RFID technology has been successfully applied in various cases. For example, RFID chips are used during the soccer World Cup 2006 in Germany for entrance controls. Such technology makes it also possible to track visitors and support them in their wayfinding tasks, e.g., from the parking lot to theirs seats in the stadium [6]. RFID was also used to improve the position of mobile robots and persons in their environment. With RFID tags it is possible to create maps using mobile platforms that are equipped with RFID antennas which assist localization [3]. RFID technology can be used to collect environmental data and build up a Bayesian network for positioning [2].

3 Mouse tracking in SNE

To get meaningful data describing the movement of mice, some structural changes had to be considered and realised in the SNE constraining the mice to pre-defined pathways.

3.1 Hardware setup, antenna and cage design

In use is a RFID system (Trovan Electronic Identification Systems) consisting of reader (LID 665 Miniature OEM Board), ring antennas (air-core coil antenna for LID 665) and animal glass transponders (ID 100). The mice are individually marked with these small (12 mm length, 2 mm diameter) passive integrated transponders (PIT) that are injected subcutaneously between the scapulas. The IDs of individual animals can be read while traversing the electromagnetic field which is established by the ring antennas, e.g. when passing through tubes or visiting drinking places. In the setup the minimum distance between two antennas is 20 cm. Transponders are read within a 0.5 cm distance, so mice must not necessarily walk across antennas. The readers are able to read several transponders at the same time at a maximum rate of 26 Hertz.

Cage design
The cage is restructured to get information about the mice on changing floors, movement on the floors, the direction of movement, the home range of individuals, drinking and emigration behaviour. To gather those data the cage is realised as follows: The SNE is divided into five areas. The ground is divided by a wall into two sections and there are 3 floors on different levels which are connected by sloping tubes and a rope. Outside the SNE an emigration cage is provided that can be accessed from the ground floor (i.e. to give shelter to low-ranking animals within the group hierarchy) via a tube and crossing a water basin.

Fig. 2. Tube with antenna

Fig. 3. SNE cage design

To get reasonable data the antennas are placed on strategically chosen spots, i.e. where the mice must cross. Every Plexiglas tube has two antennas at the end and the beginning (Figure 2), so it can be detected when a mouse changes the floor, in which direction mice cross the tubes and also the speed of mice. In every area there is an antenna beneath the drinking bottle to get data about the drinking behaviour and to establish a warning system when a mouse does not drink. Additionally, every area contains a tube supplied with two antennas which enables to collect data about the movement on the floors and eventual dominance relationships. In total there are 27 antennas integrated in the SNE (Figure 3). With this design it is possible to collect the necessary data about movement and behaviour.

3.2 Database management for RFID-based events (Jerry TS)

To configure the RFID readers and to handle the reading of transponder codes a software called JerryTS has been developed using the programming language Java.
If a mouse enters the electromagnetic field of the antenna the transponder code is read by the RFID reader, JerryTS picks it up and sends it to a personal computer. The code gets a time stamp by the PC with a millisecond resolution and is stored online in a relational database. The table contains data about when (date, time, milliseconds), where (the antenna), and who (transponder code) appears at an antenna.

4 Analysis of animal behaviour with GIS

For the visualization and analysis of the collected data the Geographic Information System ArcGIS[1] is used. First a model of the SNE is created. Therefore a coordinate system (local Cartesian projection) is developed that fits to the large scale. The different floors are modelled as layers and the antennas and tubes are realised as a geometric network with nodes and edges containing different weights for the analysis. ArcScene, an additional ArcGIS component, which is useful for the visualisation of 3D data is enhanced by developing an extension called TOM (Tracking Objects - Moving) (see Figure 4).

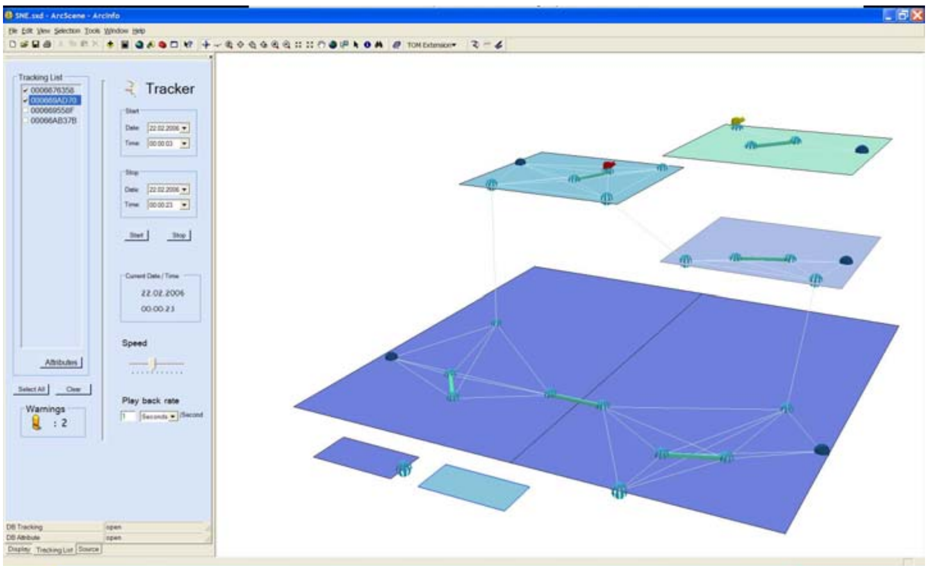

Fig. 4: TOM screenshot

TOM enables to visualize and analyse the tracking data. The position of each mouse at a certain point (antenna) in time can be visualized or the movement of the mice in time can be shown. Furthermore attribute data like the date of birth of the mice can be queried. TOM provides some statistics which analyse the collected data. The analysis is divided into the statistics per day and per level. Per day the last timestamp of drinking and weighting, the number of antenna contacts and the number of used floors is shown. The last two are a hint for the agility of the mice. Per level Information is given about the duration of stay per level, the count of antenna contacts and whether a mouse stays alone on the level or if other mice have been present. It is possible to export the data for statistical analyse with other software. The data is derived from

[1] http://www.esri.com/software/arcgis/

two underlying database-relations: one table with the tracking data filled by JerryTS and a second table where the attribute data of the mice are stored.
In addition a warning system is established, when a mouse has not been drinking for a longer time period or using the emigration cage.

5 Conclusions and Outlook

Using RFID technology facilitates the collection of time continuous movement data of fast moving small animals in a complex scenario. Twenty-four hour observation is possible without disturbing the animals. Social interaction and the outward appearance are not influenced by this technology and only a few modifications must be made to integrate the RFID antennas in the SNE.
The hardware setup is realized through JerryTS, the SNE is equipped with the RFID antennas and a new mouse population is introduced.
The arranged setting can be extended by using more sensors, e.g. a scale to get data about weight and more continuous positional data, not only point data at the antennas. Furthermore it is possible to integrate an automated learning test for the mice.

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