Indoor Tracking of Laboratory Mice via an RFID-Tracking Framework

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ABSTRACT

In this paper a solution for tracking of laboratory mice in an indoor semi natural environment based on RIFD-Technology is presented. A tracking framework is built where combined sensors identify and track the mice continuously 24 hours a day and 7 days a week. Besides the hardware setup for the data collection we present a software solution which prototypically implements an analytic module for the mouse movements.

Categories and Subject Descriptors

C.3 **[Special-Purpose and Application-Based Systems]**: Signal processing systems
J.3 [**Life and Medical Science**]: Biology and genetics

General Terms: Design, Experimentation

Keywords: RFID, Tracking, Localization

1. INTRODUCTION AND RELATED WORK

In the field of behavioral biology scientists are interested in the habitats and movement of different kinds of animals. To gather these information direct observations are made. Nowadays different localization techniques are used in the field of behavioral biology to support the observer by the data collection.

In the case of huge or wild animals GPS technology has many use cases for the outdoor tracking. For example fur seals in the Antarctic [2] are localized and even tracked by using the GPS satellites. Are biologists interested in movement and behavior of productive livestock in a controlled environment for example cows in a barn – they are tracked by using radar technology [6].

At the Department of Behavioral Biology in Muenster the observation targets are laboratory mice which are observed indoor in a so called semi natural environment (SNE). The SNE is a large cage (1.75m width x 1.75m length x 2.1m height) and covered with wire netting. Inside the cage are many levels at different heights which are connected with tubes, robes and small wooden bridges. Toys, food and water are supplied everywhere. There lives a population up to 40 adult mice.

1.1 Motivation

In this case the biologist observed movement and behavior patterns of laboratory mice which have a genetic deposition for Alzheimer's disease and want to detect differences in movement and behavior between genetically manipulated and wild type mice. In the past the data collection had been done by direct visual observations of human observers. In the described setup several problems by the observation occurred:

- mice are nocturnal animals
- identification of the mice by their color code wearing at ears and tail
- unique identification of a mice with a high error rate
- unique identification of a mouse takes long time
- difficulties to identify a single mouse out of a group of 40 animals by their color code
- limited observation time per individual
- arising of huge personal costs
- observation result depending on mood of human observer (subjective)

On the one hand there is the problem of indoor tracking, so for example the GPS technique doesn't work and on the other hand the size of the transponder has to be minimal for tracking of animals with a body weight of around 30 gram. To solve these problems the RFID-technology to identify and track the mice is chosen. The RFID-technology has many advantages for this use case, for example [1, 7]:

- contactless data transfer
- transponders can be read through different materials even skin
- fast read cycles: less than 100 milliseconds
- unlimited life cycle forever
- small overall size
- cheap

With this technology it is possible to identify and to track a huge number of small fast moving animals with low cost and effort.

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2. TECHNICAL SETTING AND DATA COLLECTION

In a first step the SNE has to be adapted to the changed conditions and the new requirements. The components of the RFID-toolkit have to be integrated in the SNE to get significant data.

2.1 Used RFID-technology

The used RFID-toolkit (Trovan Electronic Identification Systems) consists of RFID-reader, RFID-antennas and RFID-transponders. The glass transponders with a length of 12 mm are passive and have no own energy supply. The necessary energy is taken from the electromagnetic field of the antennas. Only inside the field is the transponder active. On a microchip inside the transponder a ten-digit identification number is stored. The transponders are injected subcutaneously between the scapulas beneath the neck. Even two transponders at the same time in one antenna can be recognized.

The RFID-toolkit is on the one hand used to identify the mice uniquely, fast and with a low error rate by the transponder code and one the other hand enables the localization and tracking of mice through analysis of multiple antenna readings.

2.2 Test environment

Before the SNE was structurally changed because the mice had too many opportunities to move on the levels and to change the levels, the RFID-toolkit is tested in further testing environments. In a super enriched cage (100 cm width x 34.5 cm length x 40 cm height) different setups are tested how the antennas could be integrated into a cage for many mice. In the result the antennas are surrounded with a plastic body to protect them against the mice and to fix them on the level. The drinking bottles are deposited on racks, which consists of an RFID-antenna and a short Plexiglas tube to get the transponder ID when a mouse is drinking.

In the SNE following data is collected:

- Activity on a level
- Change of level
- Duration of a stay on a level
- Emigration behavior
- Drinking behavior

The SNE has been divided into five areas (see **Error! Reference source not found.**). Two areas are located on the ground level, three more areas are installed on different levels in the cage. The levels have no connection to the cage boundaries so mice have to use predefined pathways to change the levels (see figure 2). Furthermore the cage has an exit which is connected to a water basin which ends in an emigration cage. The reason for this is that mice should have the opportunity to leave the community if the "social pressure" arises for a mouse too much. Mice live in a strong dominance order where dominate males built up their own territory.

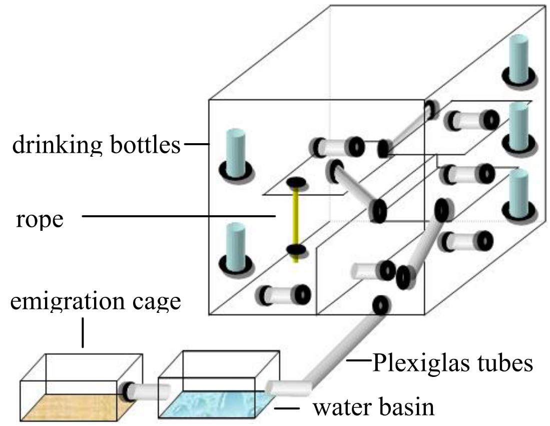


figure 1: schematically model of the SNE equipped with RFID-antennas

Two antennas are put around a Plexiglas tube to get the activity and the direction on a level and two antennas on sloping tubes are used to get data about a change of level. The emigration behavior is measured by equipping the water basin and the entry of the emigration cage with antennas. Each level is equipped with a water bottle to get data about drinking behavior. The smallest distance in this setup between two antennas is 20 cm. To protect the cable in the cage a mechanic barrier of plastic is put around the antennas

figure 2: photo of the SNE in the Behavioural Biology

2.3 Scale

In a next step a precision scale (Type 440-33N from Kern & Sohn GmbH) (see figure 3) has been integrated into the SNE to provide a facility for continuous recording of the mice weights. The scale is protected against damage with a plastic body and equipped with a Plexiglas tube and two antennas (see figure 4). The tubes section directly on top of the weighing plate is separated from the rest of the tube. Therefore the weighing plate still can vibrate freely when weighing any mouse within the separated tube section.

figure 3: Scale 440-33N Kern &Söhne GmbH

The mice are not forced to move in any specific direction within the tube. But if a mouse enters the weighing plate it is detected by one of the two antennas and the transponder code is read.

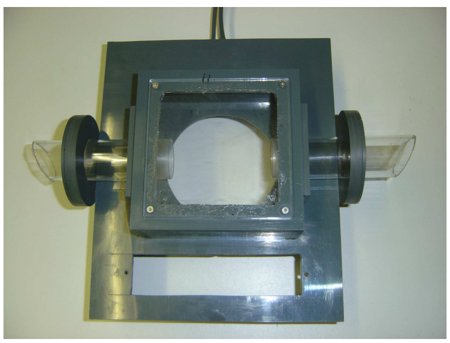


figure 4: plastic body of the scale

The scale has been configured to continuously submit the weight on its weighing plate using its RS-232 interface. Each record contains the weight value and an optional unit of weight. At the beginning of each operation period the balances setting of zero-point is adjusted.

2.4 Camera

As the last hardware component of the tracking framework a camera is integrated into the SNE. This is an usual web camera (Logitech QuickCam Pro 5000, USB) which is located above the center of highest level in the SNE. .With the aid of wire the camera is fixed under the ceiling of the SNE. The cable is positioned beyond the SNE.By using the camera although the mice's pathways between two antennas can be captured. So it is possible to capture interactions between several mice.

3. DATA PROCESSING

After the technical setup in the Behavioral Biology on the one hand software had to be designed and implemented to configure the RFID-reader, to collect the RFID-data and to store the gathered data. Furthermore software is necessary to visualize and analyze the RFID-data.

3.1 JerryTS (Jerry Tracking System)

The first software development is called JerryTS, is written in Java and used to configure the reader, to read the transponder codes and to store the RFID-data.

For the configuration of the RFID-reader different settings with this software are made. In empirical studies the optimal setting for this scenario is explored. The main problem is to have unique datasets: the mice move so fast that they can cross the tubes within one second. So a resolution of milliseconds has to be implemented with JerryTS and the read cycle has to get one transponder code per millisecond to reduce redundant entries. At least the antennas read with 26 Heart.

JerryTS stores the read RFID-data in a table (movement data) of a relational database. The table consists of the columns ID (the identification of a row), unit (the number of the triggered antenna), transponder id (the read transponder code of a mouse), date, time, milliseconds. The timestamps is made by the clock of the PC to get this fine resolution. Each row represents a single antenna contact.

3.2 TOM (Tracking Objects Moving)

The visualization and analysis of the gathered RFID-data is made with a second software development called TOM. TOM is written in C# and an extension of the geoinformation system (GIS) ArcScene from ESRI. The levels of the SNE are digitalized in 3D with ArcMap, the antennas and possible pathways are modeled with a geometric network as nodes and edges. For the localization a local geographic reference system is established [4] This frontend uses the movement data and a second table where attribute data of the mice are stored. Over an ODBC connection the MySQL database is connected to the extension (see figure 5).

With ArcMap a three dimensional model of the SNE is created an. The antennas and possible path of the mice are modeled by a geographic network, where the antennas are the edges.

The attribute data of each mouse can be queried in a dialog, so information like age, transponder ID or birthday can be obtained. In the three dimensional model the position of the mice at a certain time stamp can be visualized and the movement can be viewed in different playback rates.

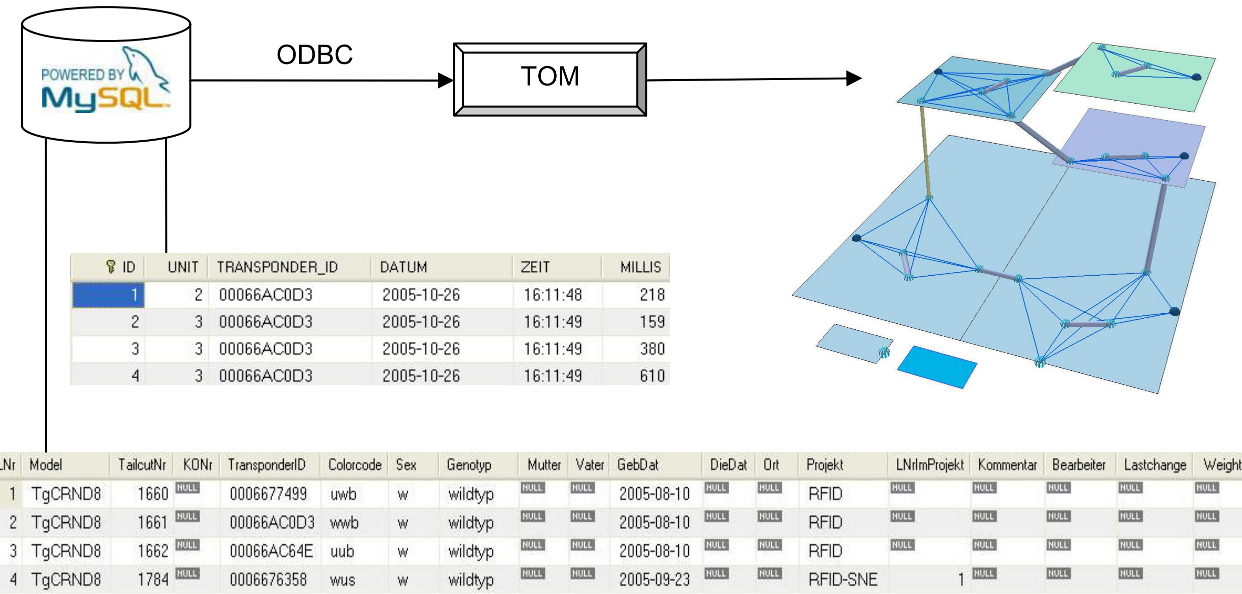
TOM consists of first analysis functionalities which are shown in a further dialog. SQL queries and algorithms are prototypically implemented [5]. Information regarding the day and the levels are provided:

Analysis per day:

- Last time of drinking
- Last time of weighting
- Number of antenna contacts in total
- Number of used levels

Analysis per level:

- Duration of stay
- Number of antenna contacts per level
- Contact with other mouse



ID	UNIT	TRANSPONDER_ID	DATUM	ZEIT	MILLIS
1	2	00066AC0D3	2005-10-26	16:11:48	218
2	3	00066AC0D3	2005-10-26	16:11:49	159
3	3	00066AC0D3	2005-10-26	16:11:49	380
4	3	00066AC0D3	2005-10-26	16:11:49	610

LNr	Model	TailcutNr	KONr	TransponderID	Colorcode	Sex	Genotyp	Mutter	Vater	GebDat	DieDat	Ort	Projekt	LNrImProjekt	Kommentar	Bearbeiter	Lastchange	Weight
1	TgCRND8	1660	NULL	0006677499	uwb	w	wildtyp	NULL	NULL	2005-08-10	NULL	NULL	RFID	NULL	NULL	NULL	NULL	NULL
2	TgCRND8	1661	NULL	00066AC0D3	wwb	w	wildtyp	NULL	NULL	2005-08-10	NULL	NULL	RFID	NULL	NULL	NULL	NULL	NULL
3	TgCRND8	1662	NULL	00066AC64E	uub	w	wildtyp	NULL	NULL	2005-08-10	NULL	NULL	RFID	NULL	NULL	NULL	NULL	NULL
4	TgCRND8	1784	NULL	0006676358	wus	w	wildtyp	NULL	NULL	2005-09-23	NULL	NULL	RFID-SNE	1	NULL	NULL	NULL	NULL

figure 5: architecture of the visualization and analysis frontend: the database which consist of two tables is connected over ODBC to the TOM extension where the data is visualized in 3D

This information gives the biologist a hint for activity of the mice, their health status and their dominance status for example. It is possible to export this data and to use them in further programs.

3.3 Scale data

3.3.1 Weight data

The weight data provided by the scale is processed in two steps. First a data reduction and second a data integration step is made. The balance submits 2-3 records per second, regardless of its state. Furthermore the scale is very susceptible to vibrations in its vicinity caused for example by people moving near the SNE or mice moving on the scale plastic body. The data submitted by the scale therefore is reduced by means of only processing a record if it reasonably differs from the record preceding it. In our setup weights must at least differ by one gram to be regarded as truly different.

Mice sometimes drop food, litter or feces within the tube section on the weighing plate or take previously dropped material out of it. This causes a permanent bias of all submitted weights relative to the scale initial setting of zero-point. Therefore a virtual tare weight for the empty tube section is maintained and subtracted from each weight submitted by the scale. The initial tare weight is zero. If the scale continuously submits a weight which differs from zero by less than a certain threshold value, this weight is taken as new tare weight.

3.3.2 Data integration

Jerry2, an extended version of the JerryTS software has been developed to record data from any sensor source in the SNE. The main purpose of this software version is to implement the second data processing step that integrates data from multiple sources to get further information.

If a weight is submitted to Jerry2 by the scale, the mice are identified which triggered the last scale antenna contact. Thus the positional information which is given by the location of the scale is used for the tracking of a mouse.

The data integration stage assigns animals to weight data and obtain positional information from it.

3.3.3 Weight determination

When several weights have been assigned to a mouse, the animals body weight is determined by a method that we call "Range period method" (see figure 6).

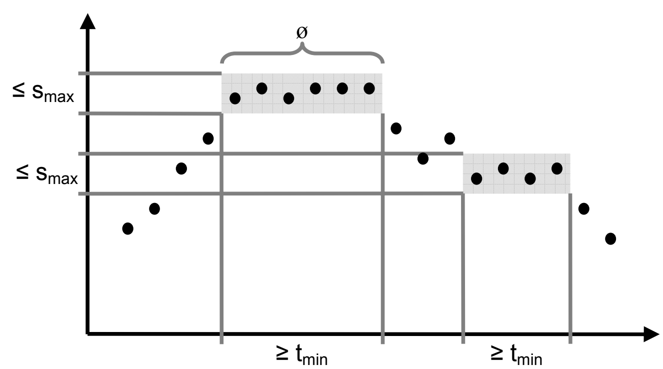


figure 6: range period method to determine the weight

This method takes a sequence of weights that have been submitted by the scale and have been assigned to a single mouse. At first a subsequences of weights is determined which values for a time of at least t_{min} have a variance of at most s_{max}. Then the subsequences mean value is calculated. If more than one subsequence has been determined the maximum mean value of all sequences is also calculated. Finally the maximum mean value is taken as the body weight of the mouse.

3.3.4 Weight analysis

Biologists are interested in long term changes of the mice body weights and also want to compare the change of body weight of multiple animals. Therefore a final data processing step for weight analysis is developed. In this step the age (when a weight was recorded) of a mouse is calculated. This is done by using a timestamp which previously has been stored with each calculated body weight. Now a comparison of the body weight of two or more animals is possible regardless of the time when the body weights have been recorded

3.4 Camera data

With the camera it is possible to observe a detail level of location in the SNE. The camera covers only a small spatial extent but has a high tracking resolution. With the combination of RFID-reader and camera a mouse which enters the filmed level is identified by the RFID-reader in the slope tube and movement and behavior are observed by the camera. For the analysis of the camera data a region of interest (ROI) is set (see figure 8).

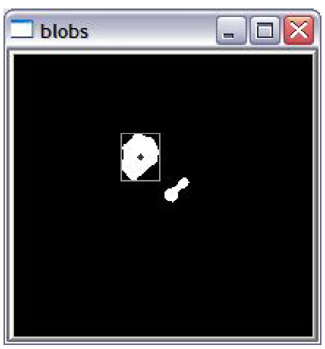


figure 7: presentation of the mouse movement as blob

Within the ROI a mouse is represented as a BLOB (big binary object) (see figure 7). Changes in the light conditions inside the observed region (e.g. resulting from movements in the environment of the cage) are reduced by using an adaptive background subtraction algorithm [3].

The optical tracking system JerryOTS realizes the acquisition of positions in an online mode (direct from the connected camera) and an offline mode (indirect via AVI files recorded by JerryOTS). However the optical tracking works in the online mode only for one mouse in the image.

In the offline mode – in combination with the recorded RFID-data – the tracking of multiple mice is possible. The problem with the tracking of multiple mice is to resolve encounters of two or more mice. In the image processing the recorded BLOBs are melted in a new one. From this point on following positions can not be allocated definitely to one mouse. With the help of the JerryTS RFID-data the passed ways are dedicated to all involved mice as an alternative way. If - at least one – mouse is seen by an RFID-antenna after the fusion, the trajectory is definitely allocated to this identified mouse.

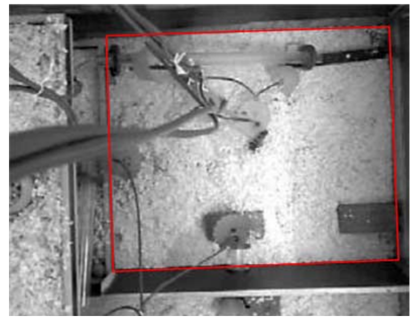


figure 8: definition of the region of interest (red)

As a result the trajectory of the observed mouse is shown to a human observer. The captured positions can be exported to several file types (e.g. csv, txt).

4. Further plans

In this project a huge amount of data has been collected and much domain specific knowledge can be used for the analysis. The analysis of the data should be continued. In cooperation with other computer science institutes data mining methods are explored on the collected movement data to detect patterns in the movement and the behavior of the laboratory mice. The aim is to classify the mice and to differ in transgenetic and wildtype mice. Furthermore for example gender-specific distinctions should be detected automatically.

5. Conclusion

An indoor tracking framework for laboratory mice which is based on RFID-technology has been established in the SNE to gather information about movement and behavior of laboratory mice. The observation takes place 24 hours / seven days a week without disturbing the mice. In connection with a scale and a camera different sensor sources are used to optimize the determination of the position and to get additional information out of the collected data. With the software solutions JerryTS, Jerry2 and JerryOTS the movement data is stored in a relational database with a resolution of milliseconds. The software extension TOM allows the visualization and analysis of the tracking data.

6. Acknowledgement

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