# Mouse-Pi: A Platform for Monitoring In-Situ Experiments

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**Abstract:** In many cases, medical research observes the behavior of animals under various conditions, such as medication or surgery. Some research in the field of Parkinson's Disease monitors when and how often rats spin around their own center within a small container. Normally, the monitoring system consists of a thin wire and an external rotary encoder. This experimental setup imposes significant stress on the subjects, and has very limited resolution in time. The present paper investigates the utility of state-of-the-art embedded systems as a core of a vision based monitoring systems. It turns out that low-cost platforms, such as the Raspberry Pi, work well in this application field. However, the chosen approach behaves sensitive to the chosen colors, the ambient light condition, and the subject’s fur.

## 1 Introduction

Prior to the authorization of new medical procedures and medications, all clinics and pharmaceuticals conduct extensive in-situ studies in order to guarantee their reliability as well as effectiveness. One research avenue that is been receiving progressive attention is known as Parkinson's Disease. Parkinson’ Disease refers to a disorder of the central nervous system that affects the motoric system. Research at the Institute of Anatomy at the University of Rostock aims to develop new treatment and therapy methods for this disease. Their approach is based on the application of Botulinum-Neurotoxin-A [AHM13].

In their experiments, the research group focuses on how fast, how often, and in what direction the subject, a rat, spins around the center of its own body. Their experimental setup is summarized in Section 2. It mainly consists of:

1. A cylindrical bucket of approximately 30 cm in diameter.
2. A waist belt that is connected to an electro-mechanical rotary encoder. This encoder is mounted approximately 20 cm above the bucket.

Even though the chosen experimental setup seems appropriate, it exhibits the following four main disadvantages:

1. The wire mentioned above, can twist and limits the subject’s maneuverability.
2. The mechanical setup can measure only rotation numbers, and is thus unable to monitor body tensions.
3. Due to its mechanical nature, the system is not able to store entire episodes with fine-grained resolution in time. Rather, the system is merely able to provide net rotation numbers.
4. Furthermore, the failure of any mechanical component voids the entire experiment as detailed episodes are not available.

In order to overcome at least some of these limitations, Section 3 presents a vision-based approach. This approach consists of an embedded system, i.e., a Raspberry Pi that is connected to a 5 Megapixel camera via a flat ribbon cable. In addition, both components are placed in a robust housing. The Raspberry Pi controls the entire system. In addition it preprocesses and stores all captured video frames. It also handles the communication with a host PC that can perform additional offline data processing.

In addition to the Linux operating system, the Raspberry Pi hosts two project-specific software components: a color-blob detection algorithm for the rat monitoring, as well as a graphical user interface for its operation. Both parts are described in Section 4.

The developed system was already used in some laboratory experiments. It turned out that even though the system generally works, external parameters, such as the lighting conditions and the texture of the rat’s fur, constitute significant disturbances.

These problems have already programmed future research avenues, which are discussed in Section 5.

## 2 Experimental Setup

The research group of Prof. Dr. med Wree at the University of Rostock performs its experiments with rats. A rat is put into a cylindrical bucket which is approximately 30 cm in height and approximately 30 cm in diameter. The floor is (partly) covered with sawdust. This environment is depicted in Figure 1.

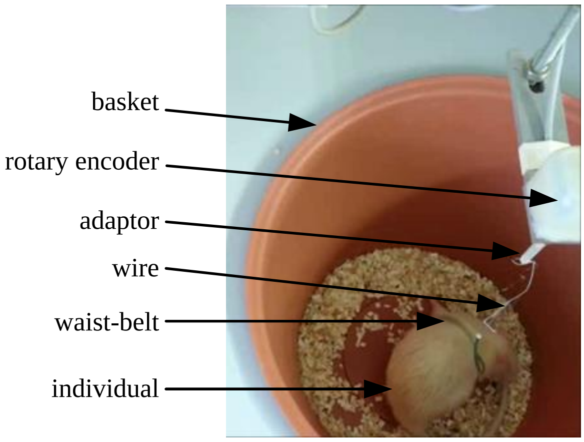


Figure 1: Experimental Setup for Rotation Tests based on a wired connection from rat to decoder

As was already mentioned in the introduction, the experiments of the research group at the University of Rostock focus on the rotation behavior of rats. To this end, they mount a belt around the rat's waist. This belt is connected to an electro-mechanical incremental rotary encoder by means of a thin wire. The encoder is mounted approximately 20 cm above the bucket. The rotary encoder is in turn attached to two separate displays that show the number of rotary steps in clockwise and counter clockwise direction. The typical experimentation time amounts to about 40 minutes. The final experimental outcome consists in two numbers, one for each rotation direction. This part of the experimental setup is sketched in the figure above.

From a theoretical point of view, the experimental setup described above is quite good. Even though it also works in practice, it nevertheless exhibits the following limitations:

1. The waist belt has to be attached to the rat manually, which generates significant stress to the subject, and might affect its behavior.
2. The connecting wire is another source of problems. On the one hand, it has to be as thin as possible in order to not disturb the subject. On the other hand, a thin wire might twist which might spoil the results.
3. The electro-mechanical rotations sensors are able to provide only net rotation numbers. Currently, no detailed rotation numbers over time are available, which significantly limits further interpretation.
4. Since the rotation encoders can only measure body rotations, they cannot detect and monitor body tensions. Body tension is another parameter that might be very important for the evaluation of the experiments.

## 3 Approach: A Camera-Based Embedded System

In order to overcome the limitations mentioned in Section 2, recent research has developed a camera-based monitoring system. It consists of two main components, a Raspberry Pi 2 [RPa16] and a 5 Megapixel regular off-the-shelf camera [RPb16]. The chosen Raspberry Pi is a second-generation model. It employs a 900 MHz quad-core ARMv7 CPU and 512 MB RAM. It provides various I/O-interfaces, including four regular USB-2 interfaces.

For the task at hand, a Raspberry Pi camera module was chosen. It features a 5-megapixel OmniVison OV5647 sensor [OVT10] and is able to deliver 30 frames per second at Full-HD resolution. The camera is attached to the Raspberry's CSI port via a 15 cm ribbon cable. The camera module is widely available for less than 10 Euros. Since this camera module was replaced by the next generation model, future systems will make use of the 30-Euro v2 camera module. The new camera module offers enhanced resolution, color fidelity and low-light performance. The system components are illustrated in Figure 2.

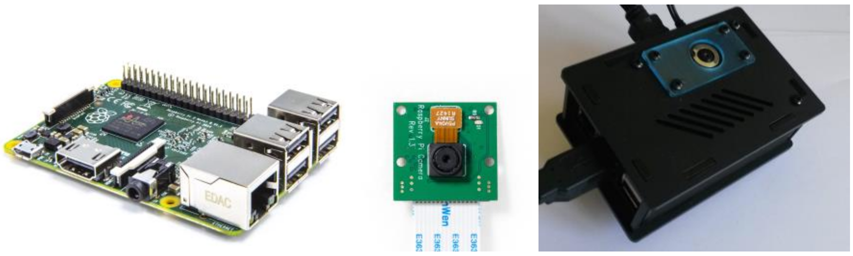

Figure 2: Raspberry Pi Development Board, Raspicam, and Nwazet Pi Camera Box (from left to right)

For storing the captured video frames as well as all results, the Pi’s internal SD-Card or an external USB-device can be used. In order to provide a robust housing, all components are mounted into a Nwarzet Pi Box, available for approximately 30 Euros.

## 4 The Software Components

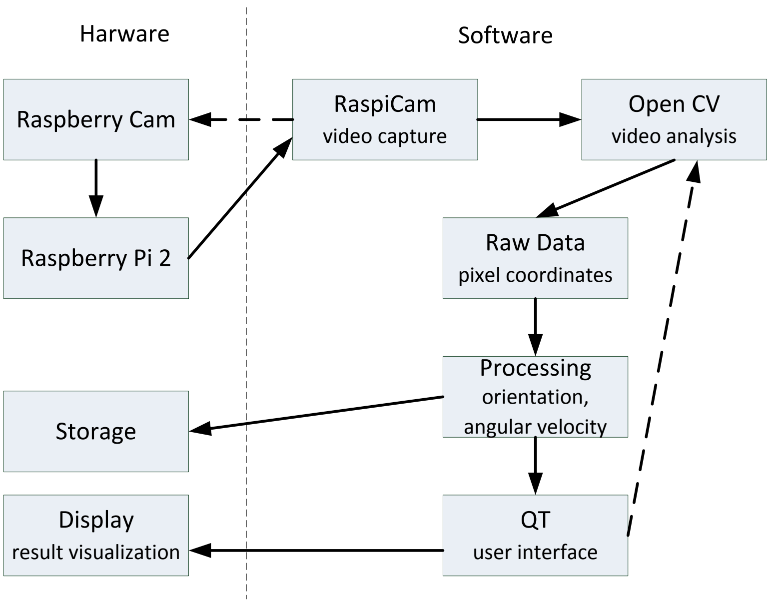


Figure 3: Structural System Overview: Functional Separation in Hardware and Software Components

The Raspberry Pi is a serious computer with all the feature of a standard PC. It runs with the Linux-based Raspbian operating system out of the box. In addition, several frameworks for video and image processing, camera access and user interface generation are available. In its current version, the system makes use of the RaspiCam framework for camera control and image retrieval. Image processing is done with the OpenCV library that offers most functions required for image analysis, object recognition and object tracking. The Qt library is used to provide a graphical user interface with user-friendly access to all setup characteristics. All processing functions that evaluate the image data and calculate the results are written in C++. The entire system is shown in Figure 3.

## 5 Experiments and Results

In the context of the aforementioned medical studies, the main purpose is the autonomous monitoring of rats, particularly their turning and twisting behavior over time. For this very purpose, the experimental procedure is as follows: The investigator puts two or three colored blobs onto the rat's fur. Then, he or she selects the current color values be means of a graphical user interface (see below) within a captured video frame. After this initialization, the software monitors and tracks the blobs, and in the end, provides detailed graphs about the subject's behavior.

The actual tracking algorithm works as follows: First, the camera grabs a frame and transfers it to a local image variable with the help of the RaspiCam framework. The OpenCV framework then recalculates the frame into the HSV color representation scheme in order to reduce the influence of the lightness and to improve the color value identification inside the frame. Afterwards, the framework identifies those pixels that have color values within the range of the selected blob color. All other pixels are removed, i.e., set to black. A contour finding algorithm in combination with a so-called momentum function delivers the center coordinates of the color blob within the frames coordinate system. Since the rat is marked with at least two colors, the OpenCV framework transfers two coordinates into the subsequent processing stage. With the help of the arctan()-function, the angle and thus the current orientation of the rat is calculated. Here, some additional calculations ensure a continuous angular value between 0 degree and 360 degree. The zero degree angle refers to a horizontal-orientated rat facing the right side of the frame. Since the orientation angle is calculated periodically, the system performs the angle velocity calculation based on two subsequent angle values. A system timer provides the timespan between two frames. All calculated results as well as the processed video frames can be displayed on a monitor attached to the Raspberry Pi.

During experimentation, the camera is mounted on a tripod such that it continuously monitors the rat in its bucket environment. Furthermore, all window shades in the experimentation room were closed to minimize the influence of changing natural light condition. The room was lighted by an overhead light. All experiments lasted for 45 minutes. The system was setup to take five frames per second since this value provides sufficiently fine-grained results as the animal’s agility does not require higher resolution in time.

The system worked fine in the practical experiments. It continuously grabbed, processed, and stored frames without any complication. However, the color identification algorithm exhibited some issues. The rat’s fur was marked with regular wide-board markers in green and blue, since these colors are distinctly separated in the HSV color model. Figure 4 shows an example frame with the identified color blobs marked with yellow circles. The angle between the two green lines is calculated to 93.5 degree. However, the rat’s fur did not allow for a uniform application of the colors. Instead, the fur’s white hairs lead to a significant disturbance of the color value. In addition, the ambient light conditions did change the color values observed by the camera significantly. Thus the system was not able to always continuously track both blobs correctly.

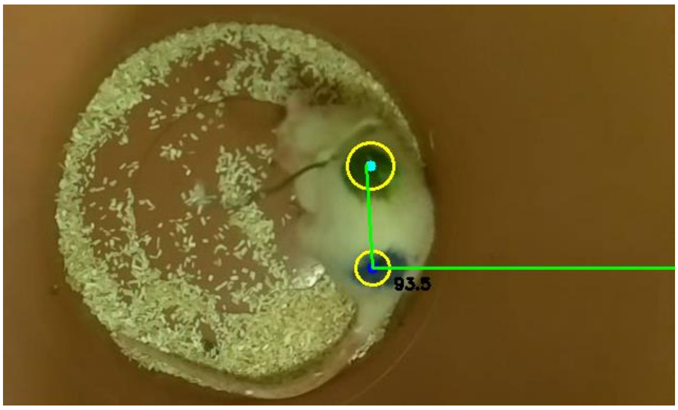


Figure 4: Individually marked rat at the bottom of the experimental Basket. The two yellow circles indicate the recognized markers while the green lines illustrate a current angle of 93.5 degrees.

## 6 Discussion and Conclusion

The practical validation has shown that the system operates well to a certain degree. When using colored blobs on paper, the system tracked the rotation very precisely. Also, all aspects concerning processing speed, storage, communication, and camera control are handled well. However, with respect to rats, the system exhibits significant problems. These problems are not due to the system's core, but are rather due to the following real-world properties:

1. The texture of the rat's fur does not allow for a sufficiently homogenous coloring; when using marker pens, the coloring remains rather non-uniform.

2. Solid blobs, such as colored papers etc., cannot be applied, since the subjects would try to remove them from their body, which in turn would change their behavior. Such a behavior would invalidate any experiment.

3. Sometimes, the blobs disappear in part due to the subject's movements. For obvious reasons, this cannot be avoided. Rather, the software has to be adaptive in that regard.

Based on the problems described above, future research will be dedicated to the following three aspects. First priority will be given to the selection of a better coloring method. To this end, the next step will be testing special animal marking pens. These pens contain a significant amount of fat in order to ensure a long-lasting and thick color layer. This might decrease the shine-effect of the white-colored rat hairs. Furthermore, future research will also include the consideration of different light bulbs with different spectral characteristics, such as LED lights, Halogen Lights, and neon lamps.

Since the fur's texture cannot be eliminated (as removing the fur is not an option), the second research avenue will be dedicated to the development of a more robust filtering algorithm.

The third research option concerns the design of the entire software package. For the first prototype, it seemed reasonable to resort to standard components, such as the OpenCV library. Due to the problems mentioned above, the authors intend to entirely redesign the current software package. In addition to the blob detection algorithm, this also applies to the tracking functionality: For further experimentation, it would be more than helpful to provide complete tracking information in more complex environments.

## Acknowledgement

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## References

[AHM13] Antipova V*, Hawlitschka A*, Mix E, Schmitt O, Dräger D, Benecke R, Wree A. Behavioral and structural effects of unilateral intrastriatal injections of botulinum neurotoxin a in the rat model of Parkinson's disease. J Neurosci Res. 2013;91(6):838-847.

[RPa16] https://www.raspberrypi.org/products/raspberry-pi-2-model-b/ (07.10.2016)

[RPb16] https://www.raspberrypi.org/products/camera-module/ (07.10.2016)

[OVT10] OmniVision Technologies Inc., OV5647 5-megapixel product brief, Version 1.0, 2010