PiRMA: A low-cost rodent physiology monitoring bed for pre-clinical experiments

Team (*primary contact)

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Marcel is a German Masters student studying for six months in Cambridge. He has a background in programming, machine learning, molecular biology, and animal experiments. Therefore, he will help to build the system and cover the biological validation of physiological parameters.

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Dom is Head of the Imaging Core Facility at the CRUK Cambridge Institute. He has wide expertise with various imaging modalities and will therefore help with design compatibility and implementation of the monitoring system in multiple imaging scenarios.

Lina Hacker CRUK Cambridge Institute, University of Cambridge; linahacker91@googlemail.com

Lina is also a German Masters student studying for six months in Cambridge. Her background is in tissue engineering, molecular medicine, and bioinformatics. She is highly experienced in animal handling and will contribute to the bed design and implementation into animal experiment scenarios such as anesthesia induction.

Summary

The aim of this project is the development and implementation of a low-cost rodent physiology monitor which is suitable for a wide range of animal experiments and imaging applications. Parameters such as Heart Rate (HR), Respiratory Rate (RR), and Temperature will be presented to the user and can be fed (via an interface) into other systems. These include Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) which often require gating information such as HR and RR to reduce motion artefacts. The rodents (primarily mice) will be placed in a bed which contains all the required sensors therefore removing the need for any further setup by the user. The bed will be designed to be compatible with scenarios ranging from anesthesia induction to image acquisition. Existing solutions are in the cost range of several thousand pounds and do not support the holistic workflow required in animal experiments.

Proposal

Problem and biological system

The monitoring of vital parameters in animal experiments is crucial for ensuring the animal's wellbeing and overall compliance of the experimenter to ethical requirements. Parameters such as depth of anesthesia can result in different physiological responses and therefore directly inflict experimental conditions and cause data deviations between individual animals. To partially overcome this obstacle, physiological monitoring suites are commercially available; these demand manifold user interactions with the setup and are in the price range of £2,000-8,000. However, the current availability of 3D printing and easy-to-use electronical components allows similar solutions in the sub £200 regime. Being able to build such a platform and thereby gather the physiological data with a low-cost system, process the parameters for visualization and subsequently allow the real-time signal export to imaging modalities would satisfy the need for an easy to use rodent monitor with modular extensibility

Design goals

The main design objective is to build an open source rodent monitor requiring almost no previous knowledge from the operator. A sketch of the system is shown in Figure 1.

Desired specifications for the system are as follows:

1. 3D printed mouse bed with inserts for HR, RR and temperature sensors.
2. Slot for heat pad insertion to regulate the mouse body temperature (controlled by another temperature sensor which uses a control loop for pad heating).
3. Anesthesia mask with one solenoid valve to allow the change of gas flow.

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3. Anesthesia mask with one solenoid valve to allow the change of gas flow.
4. Sensors, valve, and heat pad are wired to Arduino.
5. Arduino processes these data and (based on empirical values) suggests whether data is in an acceptable range. Further, the control unit adapts heat pad temperature and gas flow.
6. Prepare data for visualization on touchscreen and allow input from touchscreen to manipulate pad temperature and gas composition.
7. Alternative 3D printed mouse bed with MRI/CT compatible sensors to allow respiratory and heart rate gating.

Project implementation

We will start by validating biological parameters such as heart rate and respiratory rate using readily available sensors for microcontroller systems, and compare them to existing but costly equipment that we can access. Subsequently, the readouts will be fed into the Arduino and shown on the touchscreen. After finishing the design of the mouse bed and completion of 3D printing, sensors will be embedded and the control loop for the heat pad will be set up. The system will be programmed to control the heat pad, followed by the setup of the solenoid valve system which will allow change of gas flow. The overall design of the system will be continuously refined by using the prototype in actual experimental scenarios.

Proposed outcome and benefits

The bed will provide cheap and easy-to-use animal monitoring in pre-clinical experiments. This will facilitate reproducible animal conditions and thereby ensure the wellbeing of the animal. Moreover, it will make the results less susceptible to changes in physiological conditions involving cardiac and respiratory function. Current monitoring systems are costly and are not compatible with different pre-clinical experimental scenarios. By implementing the proposed open source concept using low-cost technology, the system can be reproduced and extended by other researchers to suit their own individual needs. In this way, the monitoring bed can relieve stress experienced by both animal and the experimenter.

Figures and Tables

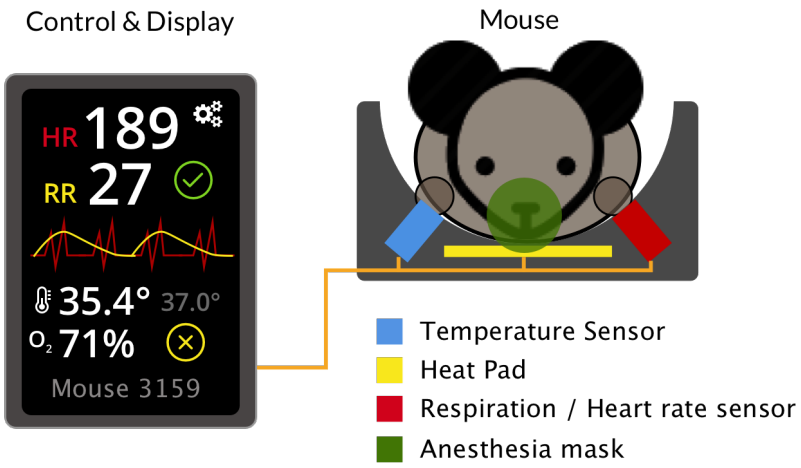

Figure 1: Sketch of the rodent physiology monitor.

Table 2: Needed components for design goal. Additional components might be required due to continuous refinement process.

Components	Quantity	Unit cost	Total cost
Physiological sensors (Temperature and Heart rate)	2	£ 30	£ 60
3D printed bed (+ filament)	2	£ 20	£ 40
Silicone heating pad	2	£ 25	£ 50
Solenoid valves	2	£ 10	£ 20
MRI/CT shielding	6	£ 4	£ 24
Respiration sensor	2	£ 30	£ 60
Gating hardware and interface to	1	£ 120	£ 120

Respiration sensor	2	£ 30	£ 60
Gating hardware and interface to MRI/CT	1	£ 120	£ 120
Total £ 374			