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Motility analysis by means of video tracked markers

Abstract: The motility of the gastrointestinal tract is crucial for digestive activity and dysfunction can lead to severe disease pattern. A method for analysing the motility is needed when treatment approaches shall be evaluated. Therefore markers attached to different locations on the stomach and the bowel of pigs are video tracked in this research study. The markers are designed to provide a high contrast and have an adhesive side for fixation. Above the operation field a video camera has been placed to film the markers during the procedure. To analyse the video data a special algorithm has been implemented. The algorithm requires a registration process at the beginning of each recording which allows the parallel tracking of multiple markers. After the registration the algorithm tracks the position of the marker frame by frame. Each frame is converted into a greyscale picture by adding specified colour values of each pixel. This allows emphasizing certain colours. The centre of the marker is determined by computing the horizontal and vertical centre of the marker starting at the corresponding marker position of the previous frame. After completion the data is stored as coordinates and a video with the marker position displayed for further processing. For advanced analysis the data can be synchronized with electromyography signals, for example. The marked videos show a promising tracking of the markers. However, if the algorithm loses track of a marker during a recording, it is unlikely to relocate it due to the successive processing of the frames. Nevertheless this method provides a simple and easy to use solution for movement detection of the gastrointestinal tract.

Keywords: video tracking, motility analysis, bowel movement

1 Introduction

Motility dysfunction results in different, partly severe disease pattern like chronic obstipation or idiopathic transit dysfunctions. Electrical stimulation might be an option for treatment as it has been shown before to alter motility. However, its effect is yet to be analysed in order to determine reasonable stimulation patterns. For this evaluation monitoring of the motility is essential.

Gastrointestinal activity is often analysed with electromyographic (EMG) recordings [1, 2]. EMG measurements are well established and easy to perform in different experimental settings. But the correlation of these signals to actual stomach and bowel movements are unclear. In order to investigate this relationship we want to record these signals synchronized to each other.

Motility has been monitored by means of strain gauges [3,4], manometry and video image analysis [5].

Video recordings can be synchronized to the EMG data and offer the possibility to localize the movement better than pressure measurements as the displacement of a marker is a direct indicator. Therefore this paper introduces our approach to analyse the motility by means of video tracked markers.

2 Methods

The data has been collected during experiments with pigs under general anaesthesia. The gastrointestinal tract has been exposed and the abdomen remained open during the measurement. The bowels has been kept warm by means of an infrared light and frequently moisturized with ringer’s solution to prevent functional damage.
2.1 Data Acquisition

An early marker design was a plain black circle, but has been replaced by a new marker design after video analysis started. Both designs can be seen in fig. 1. The new design has a similar black circle at the centre but with a yellow edging to ensure a more clearly differentiation of the black centre.

Another marker characteristic which has been modified to make the method more reliable is the reflectance. Matt materials are used to minimise the reflectance of the lighting which can cause the algorithm to lose track of the marker. The markers have an adhesive side for placement on the gastrointestinal tract of the pigs. This allows an atraumatic fixation and easily alterable relocation of the markers.

Above the operation field a camera has been installed to record the movement of the markers. The framerate and resolution have a great effect on the outcome data. The framerate determines the temporal resolution whereas the video resolution determines the accuracy of the locations. Recorded videos have framerates up to 59 frames per second and resolutions as high as 1280x720 pixels.

2.2 Data Processing

The data processing has been carried out by a Matlab script. The script requires a registration process at the beginning of each recording. During this process the marker positions are initialised and numbered for later reference. Afterwards the script computes the position of the markers in the subsequent frames.

To track the marker positions the script generates a grayscale image. The grey value for each pixel is obtained by adding its red colour value to two times its green colour value. Additional a two dimensional convolution is performed to smooth the gradients of the image. The size of the convolution mask is adjustable but the default size is a small two by two matrix. The computations lead to a very bright grayscale picture as seen in fig. 2.

Starting the detection of the new horizontal centre based on the previous marker position, the script moves one pixel at a time to the right until a chosen threshold value is reached. The threshold value is set to 240 by default, in which 0 stands for black and 255 means white. The script then moves in the other direction until the threshold value is again exceeded. The middle of the resulting line is set as the new horizontal centre of this marker. The procedure is repeated to find the vertical centre in the next step. This way the script processes each marker on the image and sequentially every frame of the whole recording.

The determined coordinates are stored in a binary Matlab file (.mat). Additionally the file also contains the framerate of the video, a vector with the timestamps of the specific frames and the filename of the processed video.

2.3 Data analysis

For data analysis and display Matlab can be used as well. To display the data it can be conditioned in different ways: The coordinates can, for example, be used to calculate the displacement of the marker with the initial position as reference point. This provides values that can be compared regardless of the direction of the displacement. The displacement data can be smoothed with a filter. A 3rd order Butterworth low pass filter with a cutoff frequency of 0,125 Hz is used to remove the breathing related displacement from the signal. Another option is to display the changes of the coordinates relative to the position in the previous frame and not the first. This is unsuitable to
display slow movement but does display the activity without the need of a fixed point to which the displacement is measured.

3 Results

In most cases tracking of markers with the new design was successful as seen in fig. 3. In some cases however the script lost track of the marker. Once lost, the script is most unlikely to be able to relocate the marker again due to the successive processing which uses the location in the previous frame as starting point.

There are several reasons for the method to lose track of a marker: The most likely one is visual obstruction. Visual obstruction can be caused by any object between the marker and the camera. Even thin cables can cause the method to lose track of a marker. Another reason is reflexion which makes the marker appear light-coloured. Even after using a matt material for the new marker design, reflexion is still a problem and can cause the method to lose track of a marker. The frequency of loss of track is dependent on the reason for the loss. A stable recording without any visual obstructions is unlikely to lose track of a point but a visual obstruction like a hand can cause the method to lose track of all the markers in the recording.

The higher the framerate and the resolution, the better are the results. However, even the framerates of 38 provide good temporal resolution. Video resolutions of 800x600 pixels on the other side are not sufficient for markers with a thin yellow edging.

4 Discussion

The method provides a simple way to track movement of pig stomach and bowel and could possibly be used for other applications. However there are a few drawbacks: The method does not yet identify the markers itself. That is why the registration process is needed to define the start positions for each marker in each recording. Due to this the method cannot find a marker again once it loses its track.

Another drawback is the reduction of the complex movement of the bowel to a two-dimensional plane. The method does not consider distance of the marker to the camera or tilting of the marker. That is why the unit for the displacement of the marker can only be expressed in pixels.

The method also proved unreliable in case of framerate drops or stuttering of the video. It often lost track of the marker due to these effects. Therefore a stable framerate and video recording is necessary.

In conclusion the drawbacks of the method due to the simplicity can be minimized by proper equipment and test setup.

Combining the markers with EMG electrodes at the same locations and recording the data synchronously enables us in the next step to correlate EMG signals with the motility and to evaluate the effect of electric stimulation on motility.

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