Program for Automated Motion Detection and Number Recognition

(in a repeated task setting)

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1 MATLAB version

a. Functionalities

- The ultimate goal is to analyze task performance improvements in a repeated-task environment upon wearing exoskeletons/suit and not wearing them by a number of metrics. In order to measure the efficiency improvement of exoskeletons in such repetitive work settings, some observed metrics are held in interest in this program, including the time it takes to complete a cycle of the given task, heart rate changes and weight of applied force at the point of contact with the device.
- The duration of each repetition is detected in the program by motion detection, where the current running frame is compared against the frame at which the user specifies the region of interest (by mouse click and release). The underlying conditions for detection of this changes in the pixels rely on the structural similarity index and the number of different pixels between the two frames being compared. For this particular force measurement videos, these two measures give rather clearer distinction between the two frames than the peg drilling task, where shadows and light settings affect the view by imposing dark pixels on regions over which the drill moves – this difficulty in distinguishing whether another object is introduced in this region makes it a bit more difficult to extract differences simply from 2D color-dependent views from the video.
- For recognition of digits for the heart rate and applied force measurements, there were two general approaches considered in the process – Optical Character Recognition (OCR), and a deep-learning training model. The latter relies on a pre-trained model, where numerous images of digits are necessary to train and may still not be as effective, whereas the former is lighter in terms of space and time complexity but is often more prone to error due to several factors, including, but not limited to, angle and resolution. After experimenting process with transformations on several isolated views, the heart rate was read correctly most of the time. As for reading force measurements, the angle, light settings (brightness in the device) and difficulty in clear visibility of the digits even with bare eyes impose even further failures in reading the digits correctly. During several experiments, rotations and 4-point perspective transformations have been applied to zoom into the screen; however, from the available videos it was not possible to read all digit segments from the angle, and thus the current program does not take into account force readings.

b. Dependencies

- This MATLAB version requires installation of **Computer Vision Toolbox** for image-processing and OCR functions.

c. Usage / Instructions

- Upon running the file in MATLAB, a GUI will be displayed. Then load a video to scan, and follow the pop up message directions (highlight region of interest, and another region for heart rate reading). Then it will automatically run through the video, outputting cropped region/heart rate region, and a list of measurements (time and heart rate) for each rep below. One difference from the Python version is that the highlighted region for the number (heart rate) works good enough in most cases, and thus there is no option for 'default' region. There is also an optional manual button to override false motion detection, in case something passes by, and detects as a rep, when it should not. This number is accepted if in range [50, 180], with consideration particularly for practical heart rate readings.

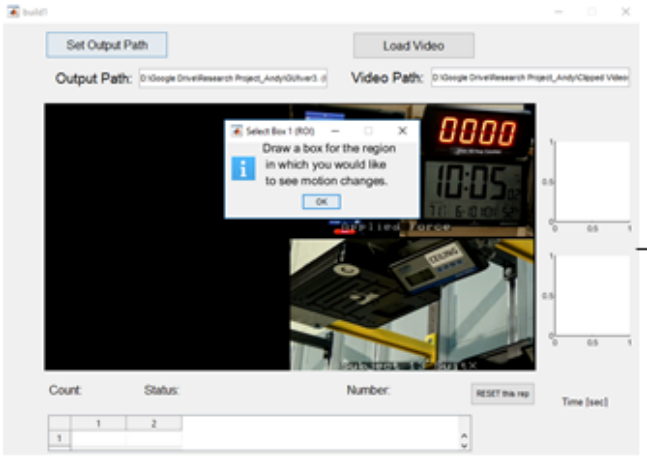
d. Constraints / Limitations

- Without skipping a couple video frames, the runtime of the program could take approximately as long as the original video run, depending on the machine. This program thus, in order to speed up the process a bit, skips 3 frames every time it loads a new frame. Since the movement in the video is not so fast that it is lost by skipping a few, this is within tolerance level in terms of detecting motions. Since not precisely coordinated, the time intervals may be different for different machines; it goes at a rate of one frame per almost every 0.2 seconds, which means it has error within bounds of +/- 0.1 seconds for time duration measurement.

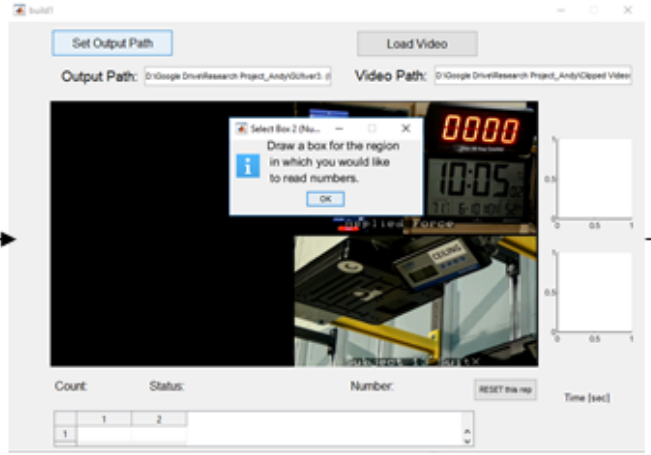
e. Output Files

- In addition to what is shown in the window while running, a CSV-formatted file containing the start time, end time, duration of each rep, and minimum, maximum, and average heart rate is produced at the end, all in a single row labeled by the iteration. The very last row contains an average statistic of each column, labeled as iteration = 0 – only to note uniquely in the index.

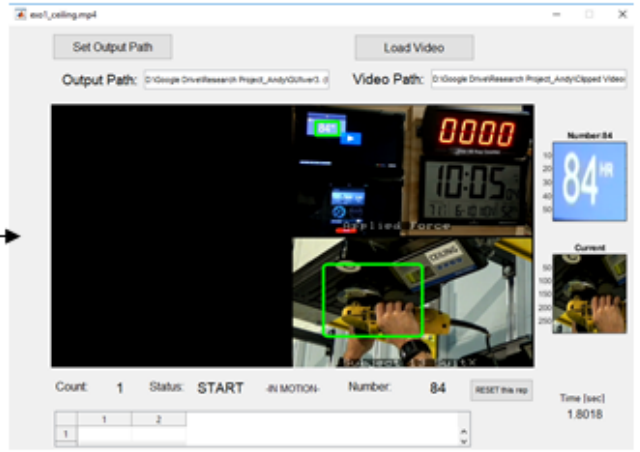
Flow Diagram for the Program (MATLAB)



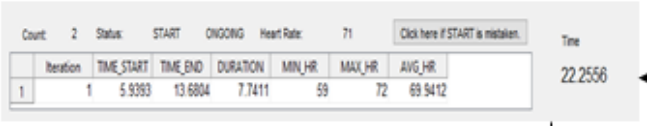
Select Region for Motion Change



Select Region for Number Reading



Motion detected
* Shows cropped images while rep is in motion

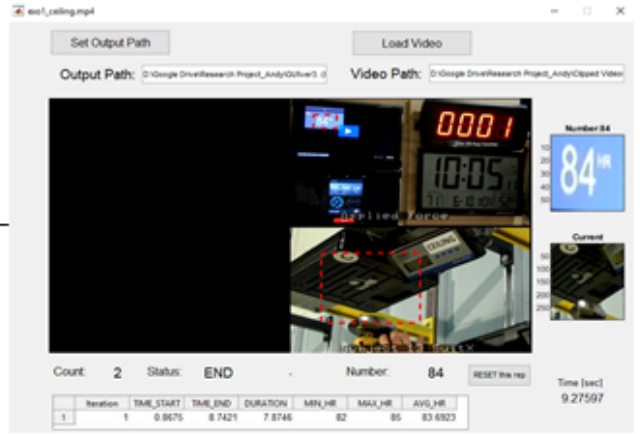


Output per iteration

	A	B	C	D	E	F	G
1	ITERATIONS	TIME_START	TIME_END	DURATION	MIN_HR	MAX_HR	AVG_HR
2	1	5.9393	13.6804	7.7411	59	72	69.9412
3	2	16.7501	24.6247	7.8745	68	73	70.4146
4	3	27.9614	36.3698	8.4084	70	74	71.3523
5	4	39.3061	47.581	8.2749	69	74	71.5714
6	5	55.0552	63.3301	8.275	59	73	70.8136
7	6	66.5333	74.8083	8.275	71	80	77.3256
8	7	79.2127	88.155	8.9423	78	90	83.61
9	8	94.4279	102.7029	8.275	89	94	91.4679
10	9	106.44	114.448	8.008	87	91	88.4659
11	10	118.3186	126.727	8.4084	87	90	87.8043
12	0	0	0	8.2483	73.7	81.1	78.2767

Output at the end (csv)

Manual override if an undesired object caused it to start recording



No motion detected