Motion Magnification and Analysis of Video Microscopy Images

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LESMAN Lab
Bio-mechanics of living cells

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Abstract

Today there are several known periodic motions of biological cells, *e.g.*, isolated cardiac cells spontaneously beat, and non-cardiac cells were shown to cyclically pull against their surrounding environment. We hypothesize that many types of cells preform small periodic movements which are imperceptible to the human eye even through standard video microscopy.

Our aim is to develop an experimental analysis tool that will help to expand the research of cells motions, focusing on small periodic movements.

The tool we developed allows:

1. Preprocessing methods for denoising and visibility improvement of video
2. Finding dominant motion frequencies in a video sequence
3. Magnifying motions at a specific frequency (Eulerian Video Magnification - EVM).
4. Finding the location and direction of the magnified movements.

References

1. Harary, Isaac, and Barbara Farley. "In vitro studies of single isolated beating heart cells." *Science* 131.3414 (1960): 1674-1675.
2. Wadhwa, Neal, et al. "Riesz pyramids for fast phase-based video magnification." *2014 IEEE International Conference on Computational Photography (ICCP)*. IEEE, 2014.
3. Wu, Hao-Yu, et al. "Eulerian video magnification for revealing subtle changes in the world." (2012).

Method

Input confocal microscope video sequence

Step 1 – Preprocessing: denoising and visibility improvement.

Step 2 - Spectrum estimation and finding dominant frequencies.

Step 3 - Video magnification using Eulerian approach.

Step 4 - Finding movement location and direction.

Step 5 – Experimental conclusions and building advanced experiments.

Validation

To validate the tool performance we took a video of periodically stretched gel using a confocal micro-scope. The gel was stretched at a frequency of 1Hz. Movements in the raw time lapse data are imperceptible. The first step was to check that the dominant frequency was indeed 1Hz.

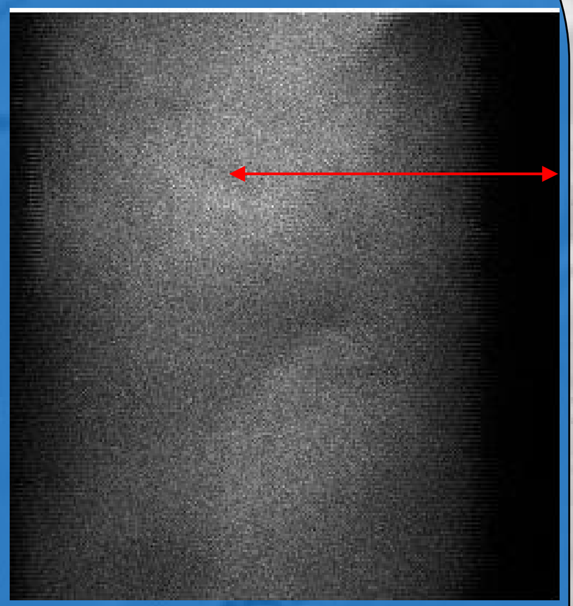

Figure 1- typical frame of the validation video, the red line marks the pixel line for yt plot in figure 3

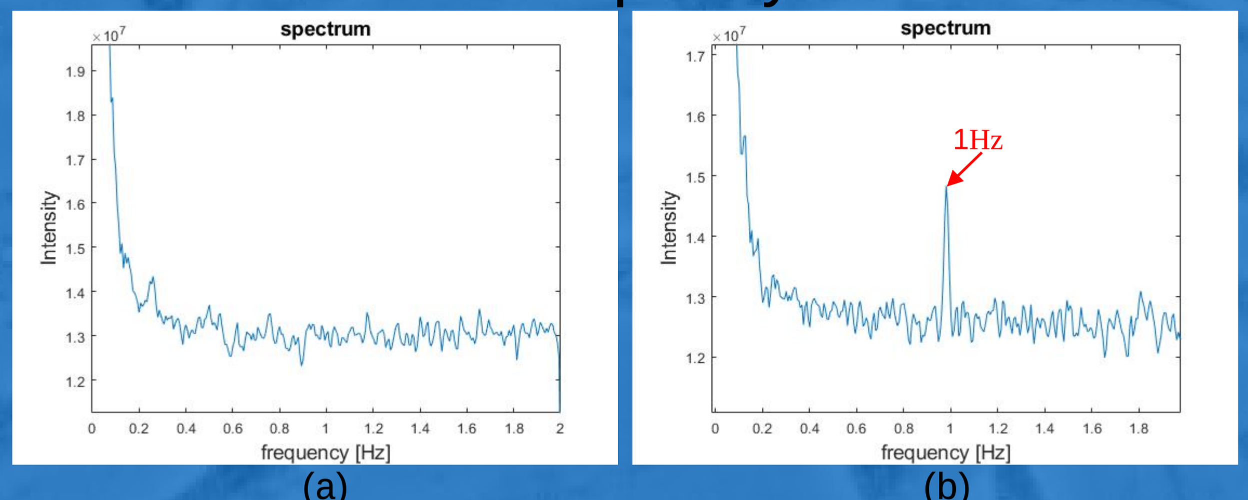

Figure 2 - spectrum estimation of the edge pixels for static video (a) and video with 1Hz small movement (b). In (b) we can see dominant frequency of 1Hz.

The second step was amplifying the motion

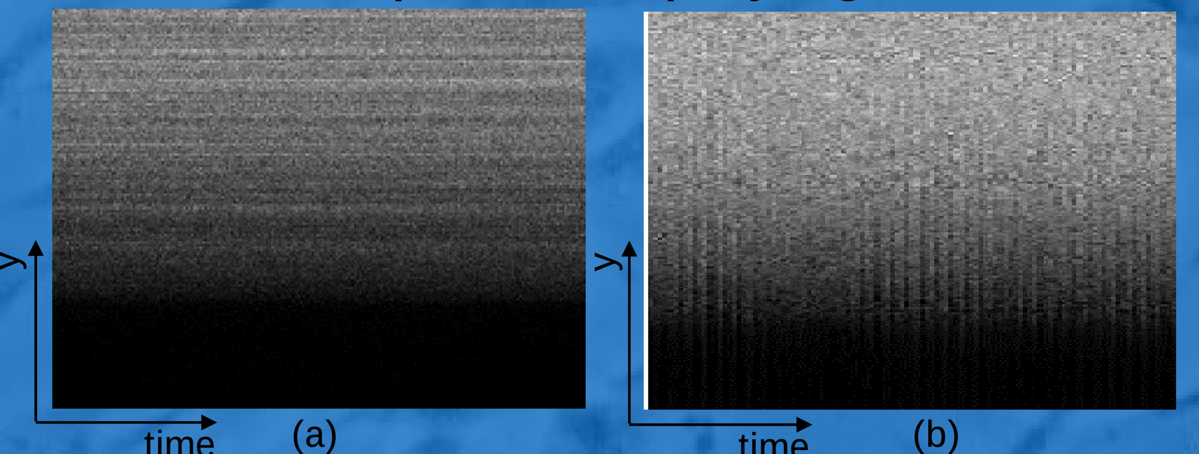

Figure 3 – yt plots, the marked line in Fig. 1 along time for the original video (a) and for the magnified one (b)

The last step was finding the effect of increasing the amplif-ication factor on the mean square error (MSE) between the original video and the amplified one.

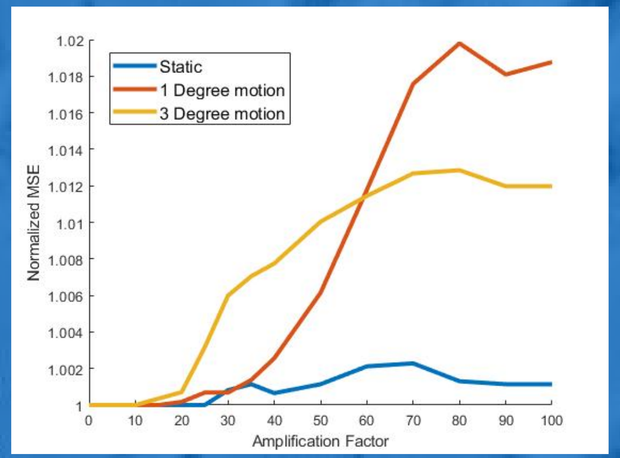

Figure 4 – Normalized MSE between original video and amplified video as function of amplification factor for 3 intensities of stretching

Results

The method was demonstrated on a live fibroblast cell embedded in a gel (Fig. 5). The dominant frequency found was 1.28Hz (Fig. 6). In figure 7 we can see that before the amplification the cell seems to be static, but after amplification the cell moves periodically along the radial direction.

Periodic movements were found in 5 videos at frequencies between 1Hz to 2Hz. In addition, we didn't find motions in videos of a fixed cell with the same amplification factor.

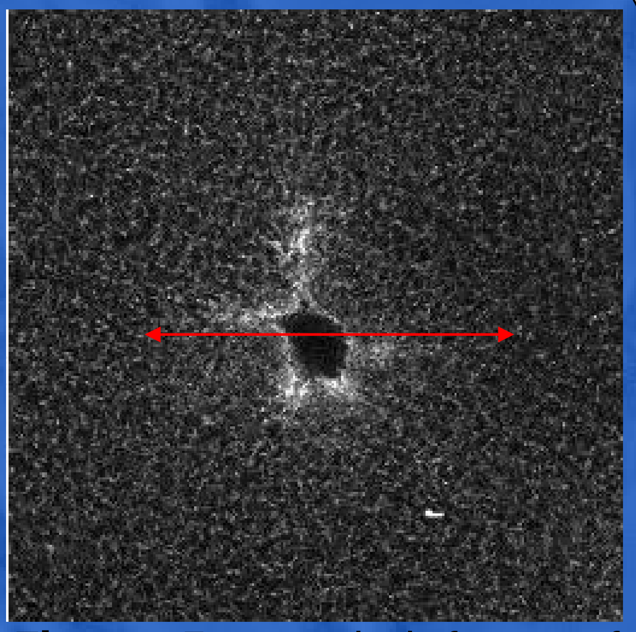

Figure 5 – typical frame of confocal microscope video, in the frame shown the area of the cell. The red line marks the pixel line for yt plot in figure 7

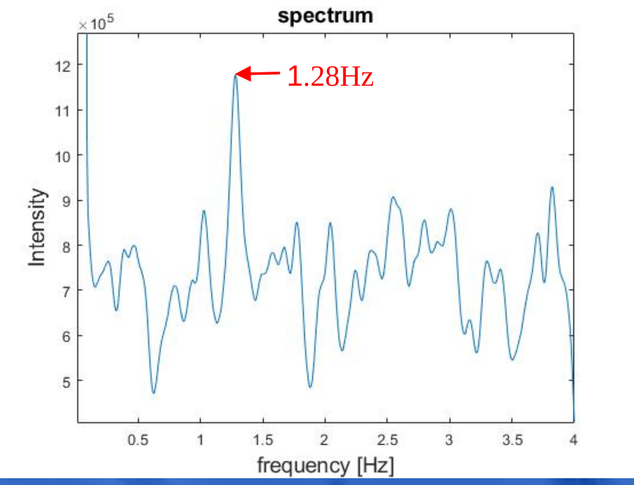

Figure 6 – spectrum estimation of the video.

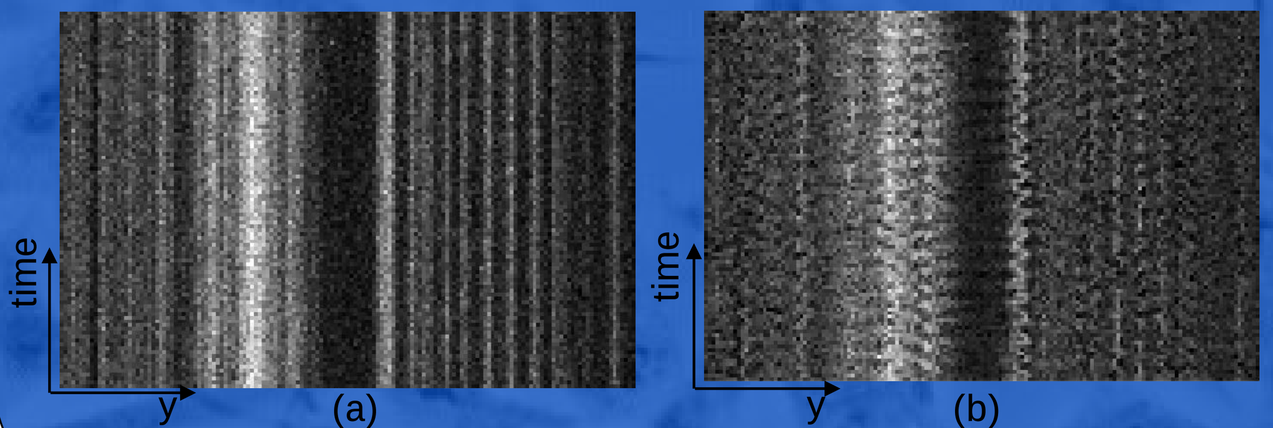

Figure 7 – yt plots, the marked line in figure 5 as a function of time for the original video (a) and for the magnified one (b)

Conclusions

We provide preliminary evidence that (non-cardiac) cells preform periodic imperc-eptible movements. Our tool can be used to examine the role of periodic motion on cell function, and to test if certain cells can be categorized by their movement frequency, e.g., differentiating between cancer and non-cancer cells. In addition, one can study the motion properties and how it propagates in the tissue, influencing distant cells.