SwarmSight: Open-source software module for real-time, paint-free tracking of insect appendage movements using commodity hardware

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Abstract Body (1800 char limit (MS Word "characters (no spaces)" number)

Machine vision methods can greatly improve the efficiency of assessing animal behavior. In previous work, we described the open-source SwarmSight software (Github.com/JustasB/SwarmSight) for assessing animal group activity from videos [1]. Here we extend SwarmSight to analyze antenna movement from videos, with real-time speed processing (~30 fps). In the past, antenna movement analysis has required high-speed cameras and painting of the antenna tips [2], or lengthy (7.5 sec/frame) processing times [3].

We demonstrate the approach by obtaining the x, y and dominant angle sector locations of flagellar tips from conventional camera videos of restrained bees (Fig. 1A). We validate the software accuracy by comparing the tip locations found by two humans to the locations found by the software in several hundred video frames. Inter-human disagreement was 10.9 pixels (px) on average and within 30 px in 90.3% of the frames. The software was a mean of 8.5 px – and within 30 px in 99.2% of the frames – from the closest human location (Fig 1B).

We presented two odors to 23 restrained female bees (*Apis mellifera*) to assess the software's ability to measure temporal changes in innate antennal movement patterns. Videos of bees presented with pure and 35x diluted versions of heptanal and heptanol were analyzed with SwarmSight to track the dominant sectors (Fig 1C) and tip x, y locations (Fig 1E). For both odorants, dominant sector and angle means at both concentrations were significantly different (Holms adj. t-tests $p < 0.01$, Shapiro tests N.S.) from pre-odor-presentation means (Fig 1D).

Overall, SwarmSight enables efficient and accurate tracking of bee antenna tips without requiring special animal preparations or equipment. This approach can be used to automate behavior assessment of appendage movements for bumblebees, crickets, ants, and other insects.

References

[1] Birgiolas, Justas, et al. *Behavior Research Methods* (2016): 1-12.
[2] Cholé, Hanna, et al. *Learn. Mem* 22 (2015): 604-616.
[3] Shen, Minmin, et al. *Journal of Neuroscience Methods* 239 (2015): 194-205.

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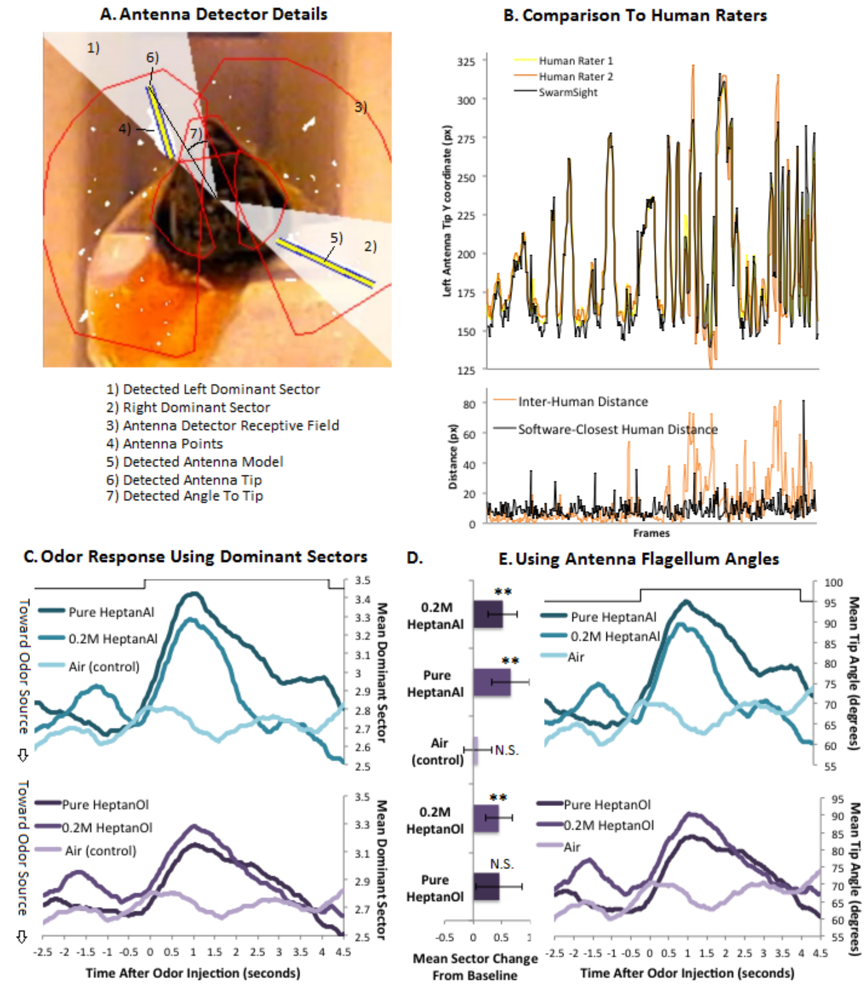
Figure 1



A. Video frame of a restrained bee and corresponding software antenna models and dominant angle sectors. Both sides are divided into five sectors, with Sector 1 enclosing angles 0^{o} to 36^{o}, and 144^{o} to 180^{o} for Sector 5. **B.** Comparison of human and software tip location detection. Top: Raw values of Y coordinate of left antenna tracked by two humans and software. Bottom: Inter-human rater per frame distance and software-closest human distance. **C.** Mean dominant sector per frame 2.5s before and 4.5s after odor presentation. Positive values are away from the odor **D.** Mean change in dominant sector from pre-puff baseline sector means. **E.** Mean tip angle per frame under same conditions as in C.