Combining EMG Recording and Robust Tracking for Insect/Robot Mixed Society

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Abstract: This work presents new developments for the behavior study of free moving insects. Crickets of the species *Gryllus bimaculatus* are marked with small circular bar codes and an overhead consumer high-definition camera is used for recording their movements. This allowed the accurate and robust tracking of id, position and orientation of up to 16 individuals simultaneously. A micro-robot is used for provoking behaviors in a controlled way, while a thin cooper wire is used for recording the corresponding muscle activity. Later tracking data is combined with the recorded waves of muscle activity for a thorough behavior analysis.

Key Words: cricket, micro robot, mixed society

1. Introduction

In recent works we have proposed a system that uses micro-robots for the behavioral study of field crickets [2],[3]. Our setup had the potential of allowing us to trigger specific insect behaviors, enticed by controlled stimulus cueing assisted by the use of micro-robots, triggering, for instance, courtship or agonistic behavior. For instance, we managed to find some evidence that subordinate crickets are more sensitive toward selective cues. Those studies showed how the mixed society setup could be used for probing crickets' behavior toward different cues. The main advantage of that system was the possibility for consistent controllability and repeatability thus allowing the researcher to perform systematic investigations on insect behavior.

In this paper we present improvements on the tracking system that allow more robust results and deeper thorough tracking of up to 16 insects simultaneously. We also show some progress in the combination of EMG recording with motion tracking for a more complete assessment of the insect's responses. We hope that together with the aid of micro-robots for controlled stimulus cueing these improvements will help us understand how animals receive, integrate and process information about the environment, and how they use this to produce motor signals.

2. Tracking

In our previous work at most two agents were marked on top with distinctly colored spots. Then a threshold operation in RGB component space was performed twice on each frame of the captured video image so as to isolate the distinct colors of the markers of each respective agent in the images. This allowed us to unambiguously identify and locate both agents, but this method had the disadvantage that it could not be easily scaled. When agents move (specially crickets) the angle of incidence of light on the markers change causing the perceived colors to shift on the captured image. The more colors are added, the more difficult it gets to ensure robust unambiguous tracking. Another disadvantage of that method was that it did not allow us to assess the orientation of each agent. For instance, for the study of cricket agonistic behavior it would be useful to be able to distinguish when two agents approach each other face-to-face.

In this work we propose a different approach inspired on our experience in camera tracking for robot soccer applications [1],[4]. We designed a set of barcode markers whose code was encoded in the choice of two distinct colors for each of the sections of a binary disc (see Fig. 1). Note that these markers must not be symmetrical and they must not be shifted variations of each other, as this would lead to ambiguity. In Fig. 2 we show a set of 16 distinct markers. Figure reffig:calibration illustrates the main steps before the bar code tracking takes place. In order to assure robust identification of the circular bar code it is very important to find the center of the marker. We used bright white for the center of the markers, with red and black for the binary code. We placed a sheet of black paper on the bottom of the arena in order to ensure better contrast.

From our past experience we already knew this was a very robust and efficient approach for tracking id, position and orientation of a group of robots. Here the main challenge was being able to keep robustness while significantly reducing the dimensions of the markers and increasing the number of agents. To tackle that problem we used a high definition camera capable of recording HD 720p (non-interlaced). We also increased the amount of environment light thus allowing us to decrease the exposure time. This was a crucial step in order to avoid blur obtaining crisp marker images even when the agents were moving. While the robots move in a very planar fashion, crickets tend to incline their bodies quite often, slightly distorting the shape of the marker from a circle to an ellipse. This results in a resolution independent upper limit to the number of bits (sections) that can be added without compromising robustness. Through experimentation we found that 16 bits showed the best

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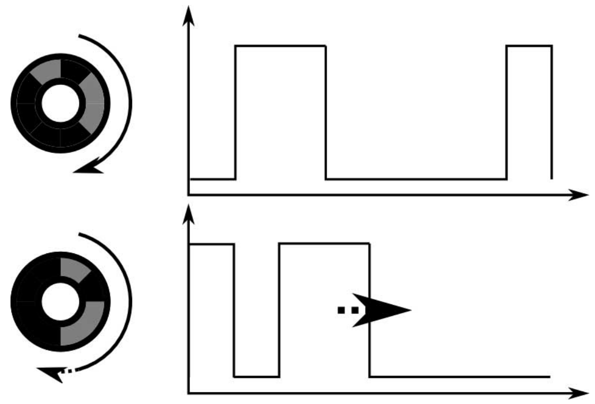


Fig. 1 After the center of each marker is located a 16 bit binary pattern is sampled from a disc with pre-defind radius. Based on the pattern and its offset the agent's id and orientation are respectively obtained.

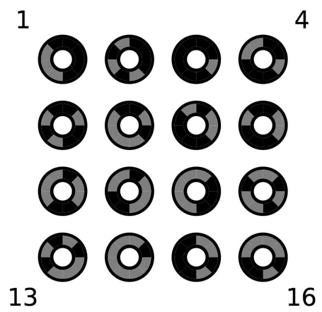


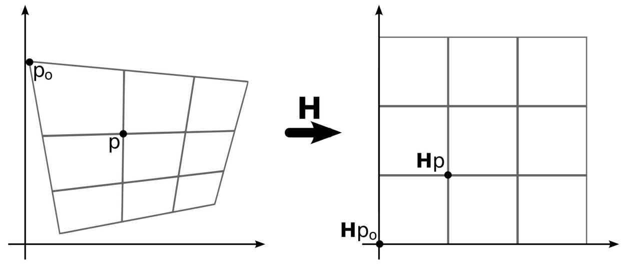
Fig. 2 Figure showing the patterns of circular bar code that are used for localization.

trade off between angle accuracy and identification robustness. Eventually an insect might incline its body further, or in some more extreme cases they might jump over each other or even flip their bodies causing occlusions. In these rare cases position and orientation can be estimated based on the surrounding frames. Interpolation can also be used as a simple way of detecting outliers, avoiding mismatches. Figure 4 shows a screen shot of a successful localization.

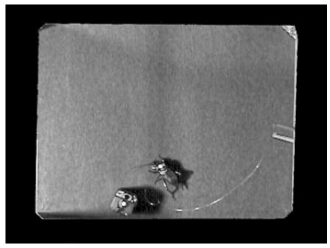
3. EMG

In previous work we have described how we inserted fine copper wires into a male cricket's mandible in order to record muscle EMG data during aggressive disputes. In that work we used a micro robot with a cue attached to it in order to entice the insect. When the cricket opened the mandibles, large amplitude EMG were recorded. When the robot retracted the activities of the mandible muscle decreased accordingly. This allowed us to control the duration of the fight.

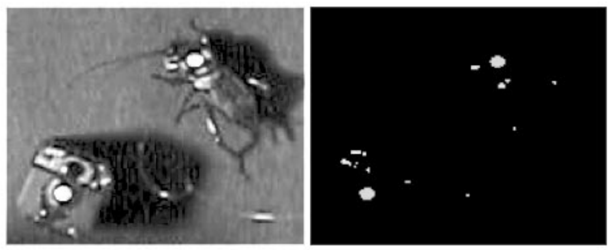
We are now in the process of combining EMG recording and camera tracking for deeper understanding of the different aspects of the social interactions (see Fig. 5). In order to do that we must synchronize the video capture with the EMG signal in order to match events that happen simultaneously in both channels. To allow that we placed a small red LED within the frame of view of the camera. We attached a step signal generator with a delay to that LED and we fed that signal to a separate channel of the electromyograph. By doing so we were able to match the step event in the EMG data with the light switching of the LED in the video.



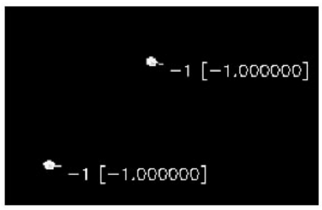
(a) Distortion Correction



(b) Masking



(c) Threshold



(d) Blob Detection

Fig. 3 An illustration of the main steps performed before the bar code tracking. (a) Distortion correction, performed based on the metric coordinates calibration points printed on a sheet, with corresponding pixel coordinates sampled in the image (2D Tsai's method [6]). (b) Masking for discarding reflexions and other optical phenomena that happens outside the arena. (c) Thresholding in order to isolate the highlights. (d) Blob detection keeps only the highlight clusters which have their area within a specified range and whose shape resembles a circle (high compactness value), discarding the rest.

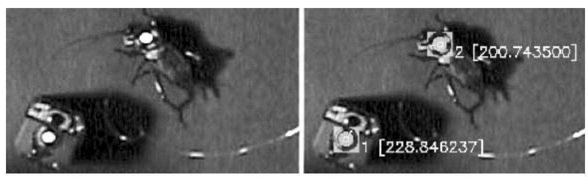


Fig. 4 Screenshot of a successful localization of two agents. The numbers in square brackets represent the cross-correlation as a degree of confidence of the match.

4. New Robot

So far in our setup we have used remote controlled micro robots for evoking different behaviors in insects. These robots do not employ any sort of sophisticated local processing. Currently we are working on an improved micro robot platform which would allow the use of local processing and the attach-

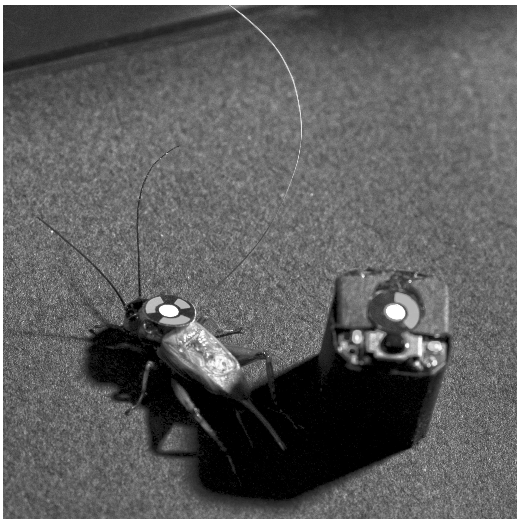


Fig. 5 Picture of cricket interacting with micro-robot, while EMG signal is captured live through a thin cooper wire attached to its mandible muscles.

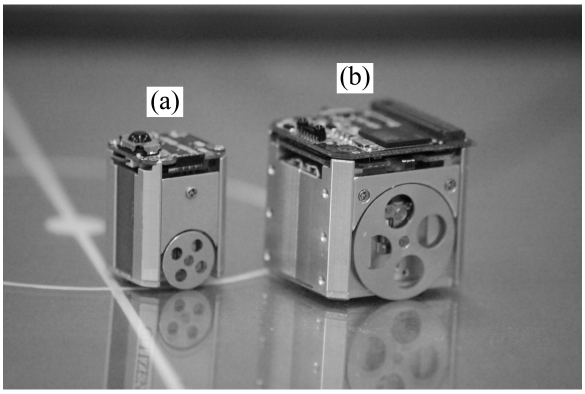


Fig. 6 Close-up picture of the two micro-robot versions, (a) the version used in our experiments so far, and (b) the newer version with more powerful embedded microcontroller and longer battery life at the expense of an increased body size. The faster processor allows installation of embodied devices such as speakers and microphones for production and detection of chirping.

ment of embedded devices such as speaker and microphone (see Fig. 6). We have recently designed an audio extension board to be attached to the top of that robot. This board includes a small speaker and two microphones (see circuits in Fig. 7). Figure 8 shows the design of the miniature audio extension board. We expect this newer system to allow better control of the experimental environment. We can, for example, examine the responses of female crickets to the calling, courtship or aggressive songs. In most of experiments working on the behavior of the female, researchers fixed animals on the treadmills or fixed the source of the sound (for instance, see [5]). Our system, however, allows the researcher to use free moving animals and also dynamically change the source of song.

5. Discussion

In this work we presented some progress in the design of a system for allowing systematic investigations on insect behavior. One of the main merits of our original research was to make possible, for the first time, the controlled stimulus cueing in a free-moving setup. This brought up the possibility for systematic behavior research in a dynamic social scenario, adding a

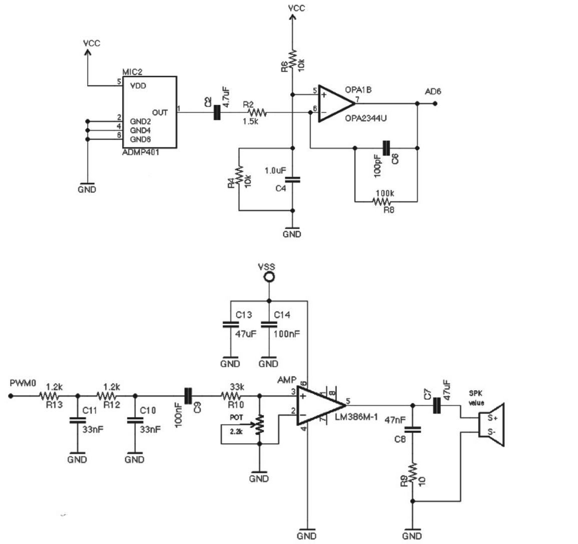


Fig. 7 Extensions being designed for the new robot. On top the circuit of the microphone and on bottom the circuit of the speaker.

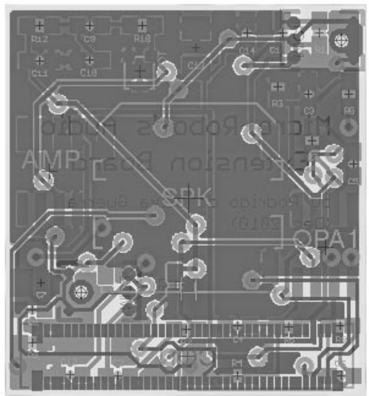


Fig. 8 Design of the micro audio extension board. On the top right one microphone, on the bottom left another. Speaker in the center.

new spin to micro-robot/insect mixed society research.

In this work we presented some important improvements that allow our system to be robustly used in more exhaustive studies potentially involving up to 16 agents interacting simultaneously. We have presented how we can synchronize EMG and video tracking data and we have shown the progress in equipping the robot with audio capabilities. We are currently working on longer exhaustive studies that will fully take advantage of these features. We strongly believe the presented setup is a great aid for the investigation of social adaptive mechanisms in insects and toward the construction of animal/robot societies.

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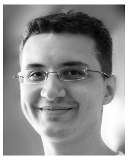

He received his B.E. in Control Eng. from PUCRS, Brazil in 2001. In 2004 he received his M.E. in Computer Vision from UFRGS, Brazil. In that same year he was awarded a MEXT scholarship to research at Osaka Univ. in Japan. In 2005 he joined the PhD course at that same univ. In 2006 he co-created the Eco-Be Micro Robot, and with it he co-invented the Mixed Reality RoboCup Competition. In 2008 he became a research associate at JST Erato Asada Project in Osaka Univ., where he still currently works. In 2010 he concluded his Ph.D.

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