# Using bat biosonar as a biological approach for mobile robot navigation

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## INTRODUCTION

Bats can successfully locate and hunt insects in acoustically cluttered environments (*e.g.* forests and caves) with extreme accuracy by the use of echolocation[1]. Since Griffin (Griffin, 1958) demonstrated in 1958 that bats orient themselves by sonar, people such as Simmons and Suga (Simmons et al., 1981; Suga et al., 1981) have contributed significantly to their study.

In this work we propose to study the bat's perceptual and motor mechanisms as a source of inspiration for mobile robot navigation. It has been shown (Peremans et al., 1993) that bats have sensor interpretation problems very similar to those of mobile robots provided with ultrasonic sensors, while navigating in cluttered environments such as forests (bats) and laboratories (robots). Hence, a better understanding of how these perceptual and motor mechanisms actually work in bats could improve in the design of mobile robot navigation controllers.

## PREVIOUS RELATED WORK IN BAT BIOSONAR

There is a lot of previous work done in sonar for engineering purposes, relevant examples being (Kuc, 1993; McKerrow, 1993; Peremans et al., 1993; Sabatini and Colla, 1998). However, we will review only some of the work relevant to bat biosonar.

The work done by Walker, Peremans and Hallam (Walker et al., 1998) on bat biosonar resulted in successful single target tracking in clutter in 2D and 3D as well as an investigation of binaural, temporal and frequency cues available to horseshoe bats. For this work, a bionic sonarhead (Peremans et al., 1997) (described in the next section) was used.

The results of their research give motivation for understanding how a dynamic sensory device can perform very accurate target localisation in a cluttered environment.

Muller also advances an interesting hypothesis about how bats do obstacle avoidance when tracking an insect in presence of multiple reflectors (*e.g.* foliage, tree branches, etc.). In this work (Muller, 1998), he addresses the hypothesis of an acoustic flow analog to optic flow being used by cf-bats[2]. According with his theory, Doppler shift and echo amplitude constitute two perceptual dimensions which bats may employ for the extraction of two-dimensional spatial information (Muller, 1998). In order to determine

[1] Bats' ability to localise targets based on the acoustical information contained in reflections of their own emitted sound pulses.

[2] Bats which emit a constant frequency pulse such as the *Rhinolophus ferrumequinum.*

if they could use or not this acoustic flow, appropriate experiments have to be done. At this point, biorobotics seems to be a valuable tool for such experiments.

## BATS AND ROBOTS

The bionic sonarhead used in our research consists of one emitter and two receivers mounted on a 6 degrees of freedom head in which 6 servomotors allow panning and tilting of the neck and independent panning and tilting of each receiver. The output signals from the receivers are passed into a transputer network which hosts the signal processing module (Peremans et al., 1997). This module models the mammalian cochlea, the output of which drives behaviours that control the motors of the sonarhead.

We are using the bionic sonarhead mounted in a RWI-B21 mobile robot as a platform to investigate the hypothetical usage of acoustic flow in bats as well as the environmental cues obtained by the dynamics of it.

Our starting point is the following research question: What makes bats hunt a specific insect in presence of several more in a cluttered environment *i.e.* how do they choose a single reflector in presence of multiple reflectors with the consequent received overlapping echoes? Our hypothesis is that bats choose one target and pursue it, ignoring the rest of the targets. For doing that in clutter we consider the possibility of bats avoiding obstacles by means of acoustic flow and tracking a specific target by the dynamics of their head and pinnae.

There are two things on which we are currently working. The first is a better model of the mammalian cochlea (either a neuromorphic chip or a software model). Our current model, because the high order of the filters used (Peremans et al., 1997), takes a lot of processing time. A better model will decrease this time and will allow us to work in closed loop, since at the moment the sonarhead works in open loop.

The second is the adaptation of Muller's acoustic flow theory to the B21. Since bats can navigate at a speed of up to 5 m/s and the maximum speed of the B21 is 1 m/s, some modifications in the model have to be done. With such speed we get approximately 0.3% Doppler shift[3]. In case of a higher percentage of Doppler shift being needed a RWI-B12 mobile robot can be used as well. This robot has a maximum speed of 3 m/s so a 0.8% Doppler shift could be obtained, though.

## EXPECTED RESULTS

We expect to obtain results which will contribute either to science and engineering (biology and robotics) as we will see next.

For the former case, our goal is to test the biological plausibility in bat perceptual and motor systems of the following two things: the usage of acoustic flow for avoiding obstacles and the influence of the dynamics of the head and pinnae for cue extraction during navigation. Hopefully this will give us some arguments strong enough to support or refute our hypothesis about the research question mentioned before.

With respect to engineering applications, real time mobile robot navigation in cluttered environments (e.g. laboratories) is nowadays a problematic task which needs to be dramatically improved if we want accurate performance. As an example, a B21 mobile robot, even though is a fully sensorized robot, will not survive in our robotics laboratory. This is because of the narrow edges of some benches, which are higher than the robot ultrasonic sensors ring, so the robot does not detect them and crashes against a bench. This particular problem can be solved by a dynamic performance of the sonarhead as stated before.

[3] $\Delta_f = \frac{v}{c} f_s = \frac{1}{350} \frac{ms^{-1}}{ms^{-1}} f_s = 0.0028 f_s$, being $\Delta_f$ Doppler shift, $f_s$ the frequency of the source and $c$ the speed of sound at 31.6° Celsius.

Also, improving the mammalian cochlear model and, as a result of this improvement, making the equipment to work in closed loop will allow the robot to perform obstacle avoidance and target tracking in real time. This is particularly important if we want the robot be a reliable tool in which to test the hypotheses mentioned in this text.

### DISCUSSION

As we have seen, the process of attempting to implement physical models of biological systems can potentially contribute to our understanding of how perceptual systems work (Walker, 1997). This is one of the important consequences of the biorobotics approach to science and engineering problems, *i.e.* only by building artifacts which interact with the real world we can understand how these systems work.


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