Tau Guidance for Mobile Soccer Robots

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Traditional approaches to mobile robot guidance have utilised an internal model of the environment constructed from sensor data in order to plan a course of action. Although this approach has been challenged by behaviour-based robotics (e.g., Brooks, 1991), the creation of "smart perceptual instruments" that attempt to directly couple perception and action has been seriously addressed by the ecological robotics paradigm founded upon Gibson's ecological optics (Duchon et al., 1995). We explore the possibility of using tau information for guidance of a mobile robot. More specifically, an attempt to implement some of the navigation techniques using tau as outlined by Lee (1998) was undertaken. Problems encountered during implementation and possible solutions are given.

Although Lee introduced the concept of using tau (*τ)* for the guidance of movement (Lee, 1998) and although tau is usually said to represent the time to closure of a gap, this is not entirely true. A negative tau represents the time to closure of the gap, while a positive tau represents the time since the closure of the gap (i.e., the gap is opening). A gap can represent a distance, an angle, a difference in force or any other gap. The information on time to closure provided by a sensor can therefore be used to control the closure of a gap and thus to guide movement. Lee also introduced the idea of guidance through tau coupling in which the ratio of taus of different gaps are kept invariant.

Method

Here we are concerned with three of the techniques discussed by Lee in which tau may be used as a technique for guidance and how they may be implemented in a system of mobile robots. The first technique has been designated as guidance by "infinite tau" (Figure l a). By keeping constant the angle between the orientation of the robot and the target direction, the tau of this angle is infinite (i.e., the gap, D, neither closes nor opens but remains constant while velocity, V, diminishes; tau = D/V*)*. The result of keeping this angle constant is that the robot will drive towards the target, spiralling around the target without ever actually reaching it. The second technique involves keeping constant the change in the rate of gap closure, tau-dot ($\dot{\tau}$) (Figure 1 b). By keeping this rate constant the robot steers in an intercepting course towards the target. The third guidance technique uses tau coupling (Lee, 1998). Figure 1c shows an example of controlling the time to closure of two angles to provide guidance to a target point. In this example a reference point is required. The gaps coupled include the gap between the robot's orientation and the angle from the robot to the target point (ROG), and the gap between the angles from the robot to a reference point and the robot to the target point (MOG). As can be seen from figure 1c, by maintaining $\tau_{ROG} + \tau_{MOG} = 0$ the robot will maintain a circular path intercepting the target. Also evident from Lee's work (1998) is that further information is available. If' $\tau_{ROG} + \tau_{MOG} > 0$ the robot is outside of the arc, and if' $\tau_{ROG} + \tau_{MOG} < 0$, the robot is inside the arc.

The three techniques discussed above were implemented on a Yujin YSR-A type robot soccer system. The system provides considerable information to the controller including details of orientations, velocities, and positions of all objects on the field. For this implementation, the only information used by the controller was the orientation of the robot, the angle from the robot to the target (in this case an orange ball), and in the case of the coupled tau implementation, the angle from the robot to a reference point. All other potential information was ignored as per the principles of smart perceptual instruments.

Results

The infinite tau technique was implemented and performed well and the robot maintained a consistent spiral towards the goal. Due to the physical nature of the robots, tight circles are difficult to maintain and eventually the robot began to move off the spiral in a "chaotic" fashion. However the robot would regain its path and begin to spiral back in towards its target point again. This same pattern was observed consistently. The technique, although never reaching its target, is useful

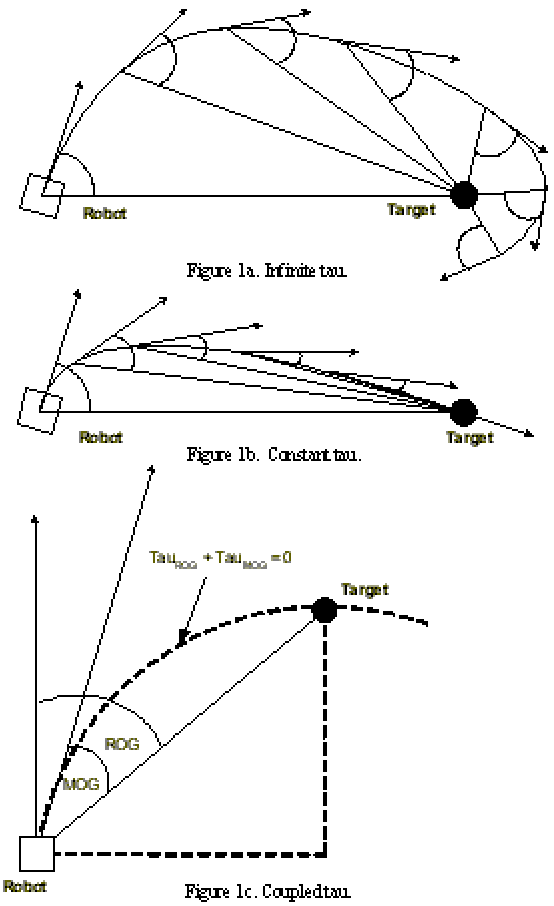

Figure 1. Robot guidance using tau

for the robot soccer domain as it enables the robot to place itself behind its target (a ball) in order to manoeuvre it towards a goal.

Problems remained with implementation of the two remaining techniques. Since the system used for implementation contained a noise component in the visual information received, errors were contained in the measurement of angles. When measuring the rates of changes of angles, such errors were magnified, which made guidance based upon ($\dot{\tau}$) information inconsistent and ineffective. Similar problems were incurred when attempting to couple two closures (coupled tau).

Conclusions

As discussed, the use of tau (especially its change over time) requires reliable sensors. Many robotic systems, including the one in which this research was implemented, contain a significant amount of noise due to imperfections in the sensors. Although some initially promising results were obtained, the reliability of the optic information prevented successful implementation of some techniques. Current work on the system involves the implementation of a Savitzky-Golay (Press et al., 1988) smoothing filter to provide more reliable data. Upon completion, further work is planned for investigating mobile robot guidance techniques that utilise invariants within an agent-environment context.

References

Brooks, R. (1991). Intelligence without representation. *Artificial Intelligence*, 47, 139-159.

Duchon, A., Warren, W., & Kaelbling, L. (1995). Ecological robotics: Controlling behavior with optical flow. In J. Moore & J. Lehrnan (Eds.), *Proceedings of the 17th annual conference of the cognitive science society*, (pp. 164-169), Mahwah, NJ: Lawrence Erlbaum Associates.

Lee, D. (1998). Guiding movement by coupling taus. *Ecological Psychology*, 10, 221-250.

Press, W., Teukolsky, S., Vetterling, W., & Flannery, B. (1988). *Numerical recipes in* C: *The art of scientific computing*. Cambridge, MA: Cambridge University Press.