Using Visual Velocity Detection to Achieve Synchronization in Imitation

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Abstract

Synchronization and coordination are important mechanisms involved in imitation and social interaction. In this paper, we study different methods to improve the reactivity of agents to changes in their environment in different coordination tasks. In a robot synchronization task, we compare the differences between using only position detection or velocity detection. We first test an existing position detection approach, and then we compare the results with those obtained using a novel method that takes advantage of visual detection of velocity. We test and discuss the applicability of these two methods in several coordination scenarios, to conclude by seeing how to combine the advantages of both methods.

1 Introduction

Synchronization and coordination are important mechanisms involved in imitation and social interaction. As put forward by psychological studies, e.g. (Hatfield et al., 1994), people often synchronize with their interaction partners using different methods, for example they synchronize their movements and rhythm. However, achieving good coordination is a very challenging problem in robotics. In this study, we take a first step to develop suitable mechanisms to this end.

In imitation and synchronization problems, the agent that is imitating (the "subject" agent) needs some inputs to know what the agent that is imitated (the "object" agent) is doing. A property often used as input information for imitation is the position of the object agent. Using position information, the subject agent can learn to reproduce or copy a trajectory. Position information can also be used to achieve synchronization—while dancing, for example.

In their studies of imitation tasks using robots, Andry et al. (2002) use the quantity of movement (temporal luminosity variation) to perceive the target position. This technique is efficient and simple as it does not need complex visual tasks such as object recognition. However, a problem with this mode of imitation in robotics is that there is always a de-

lay between the object agent and the subject one. In fact, the subject agent can start to move only after the object agent is in a new position. Even if such delay is not always a problem when following trajectory, it usually poses a problem for synchronization tasks.

In this paper, we propose a velocity detection system to synchronize the movements of two robots avoiding the delay problem. This system is applicable not only in the case of precise reproduction of movements (e.g., when mirroring a movement) but also in cases in which imitation does not need to be precise but must be very well timed at the same rhythm, such as when dancing. Our experimental results show how this system outperforms other systems based on position detection in different synchronization tasks.

Finally, to conclude the paper, we discuss the limitations of using only velocity detection in other imitation tasks and we see how we can combine position and velocity detection to improve performance.

2 Problem Addressed

In the context of an autonomous mobile robot that has to interact with other robots in its environment, the problem that we have addressed in this study aims at achieving natural and fast, adapted reactions of the robot to changes detected in its environment. Minimizing the reaction time to respond to environmen-

tal changes is very important, in particular when the limited (perceptual and computational) resources of the agent impose severe constraints. This was made possible by our biologically plausible, bottom-up approach, following which we have adopted a minimal architecture that we have built using a neural network.

We have therefore designed an architecture to make a robot follow a target or to be synchronized with the target movement. We have developed four methods for this, two of them based on position detection and two based on velocity detection: 1) position detection with Winner-Take-All (WTA), 2) position detection without WTA, 3) velocity detection with focalization, and 4) velocity detection without focalization. We have implemented this architecture in a Hemisson robot (our "subject" robot) fitted with a video camera. The target is composed of two vertical strips or a pattern of strips drawn on a white paper attached to an object Koala robot, as shown in Fig. 1.
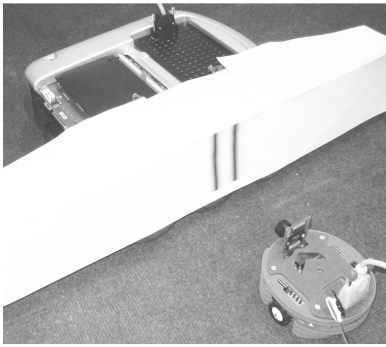

Figure 1: Experimental setup. On the left the Koala robot (object) moves the target observed by a Hemisson robot (subject) on the right.

2.1 Position detection

The basic principle is the one we can see in (Gaussier et al., 1998).

The area where the object is moving corresponds to the area of maximum luminosity difference. We first use a temporal smoothing in order to keep a small signal when the target stops moving for a short time. Then we use a WTA to set the position with the maximum quantity of movement among all the positions of the visual field. Once this position has been set, the subject agent only has to follow this position (method 1).

In fact with our bottom-up approach, we always try to build the system as simple as possible to realize the task and to take advantage of the side-effects that can be useful (Steels, 1994). In the present architec-

ture, we can simplify and remove the WTA (method 2). The new resulting behavior of the robot is not the same but is still interesting: now, the subject robot reaction not only depends on the target position, but also on its contrast and activity. The problem is that the subject robot does not move if the target has a small activity whatever its position.

2.2 Velocity detection

In order to increase the reactivity of the agent to changes perceived in its environment, we put forward the idea of using velocity of the target as input information to use for synchronization. This velocity detection method, proposed by Johnston et al. (1999), is based on the hypothesis that each object's point has constant luminosity. Therefore, the luminosity variation of an image is due only to the movement of its objects. By considering v_x the velocity of one point in x, k a constant coefficient that essentially depends on the distance to the object, and i the light intensity, we use (1).

$$v_x = k \times (\partial i / \partial t) / (\partial i / \partial x)_{(x)} \qquad (1)$$

Dividing the variation of luminosity ($\partial i / \partial t$) by the contrast($\partial i / \partial x$) is a problem when the contrast is almost null. This is not surprising since without contrast we cannot estimate the movement of an object. To solve this problem we use a threshold for the contrast: a low value of contrast (i.e., below the threshold) will produce null velocity.

We can be interested either in focusing our attention on a small part of the visual field (method 3), or in the global velocity of the entire visual field, often due to the self movement of the robot (method 4). We can use the system of position detection to focus on the target (Fig. 2).

3 Experiments

3.1 Setup

In all the experiments, we have used the Hemisson as subject robot and the Koala as object that carries the target stimulus, and we measure the velocity order that the Hemisson would send to its wheels. Since it is impossible to know the exact position of a Hemisson robot (it has no odometer sensor), we had to design our experiments taking account of this constraint: all the computations are carried out normally to produce the motor command that the subject robot should execute to follow the target but self-motion of the robot is inhibited.
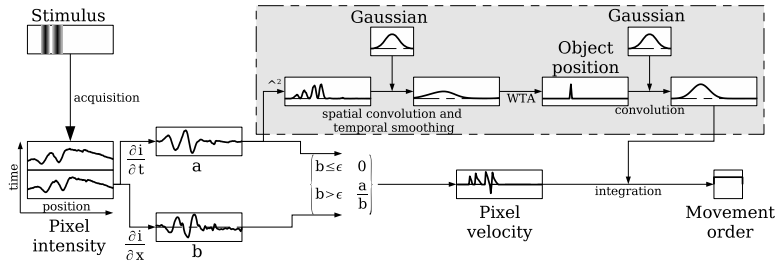
Figure 2: Architecture to detect the velocity of a focussed object (method 3). The gray part could be replaced by a large static gaussian and the architecture now only takes care of the global overview velocity (method 4). On this scheme, the curves are the result of real data.

With the first three methods, we use the same setup (see Fig. 1): the Koala robot moves right and left at a sinusoidal velocity with two vertical strips drawn on the target, while the subject Hemisson observes (without moving) the target at a distance of a floppy disk (3.5 inch). To test the last method (4) we use a very similar setup but this time the target is a wide pattern of vertical strips.

3.2 Results

We present one experimental result from a dozen with similar results in Fig. 3. The first graph shows the results of the synchronization task using position detection with WTA (method 1) and the second one without WTA (method 2). The two right graphs show the results of the synchronization task using the velocity detection, with a target's focus (method 3) on the third graph, and without focalization, but with a wide target covering all the visual field (method 4) on the last graph.

On each graph, the singularities observed over the first two iterations have no meaning. The dash line corresponds to the velocity of the object agent and the solid line corresponds to the velocity of the subject agent. Each iteration carried on for around 100 ms.

3.3 Discussion

All the methods that we have presented here have some interesting properties, depending on the task, when we want agent interactions, notably in imitation and synchronization.

The first method, which uses position detection, is very useful to follow the target trajectory. Nevertheless, the delay that it produces is not very convenient for synchronization tasks or when we have a situation that changes often.

The second method, which uses a simpler version of the same principle, is suited to follow a target position even with a small embedded system (little calculus power is needed) but also for some specific behaviors.

The third method uses focalization on the object agent defined using the detection position system. The reaction is fast and proportional to the stimulus velocity since only the area of the target is considered. This is the ideal method for synchronization in dance.

The last method, which integrates each pixel's velocity without focalization, allows us to do pure synchronization. The target position does not matter and all the visual field is considered. Therefore, if the object agent is moving in the visual field, the subject agent moves in the same direction but not with a proportional velocity since the background is considered. This method is very useful when all the visual field is moving—e.g. when the camera itself is moving. We can use this to stabilize the agent's own movements, in the same way as a fly does (Holst and Mittelstaedt, 1950). We have been able to reproduce the fly phenomenon with our robot. We put the robot in a drum with black and white strips and, when we move the drum, the robot turns with the same velocity in the same direction. The robot thus stays relative to the drum at the same place.

We can see that we have two kinds of methods (position detection or velocity detection) that have advantages and disadvantages. The first category does not produce a drift but is not very reactive. The second category is very reactive but has a drift that does not permit a prolonged interaction since the target becomes lost. To drive a system it is possible to use either the position (first order) with a stable but slow system, or the velocity (second order) with a fast but unstable system. The best results are obtained by combining both methods and this leads us to think that we should do the same.
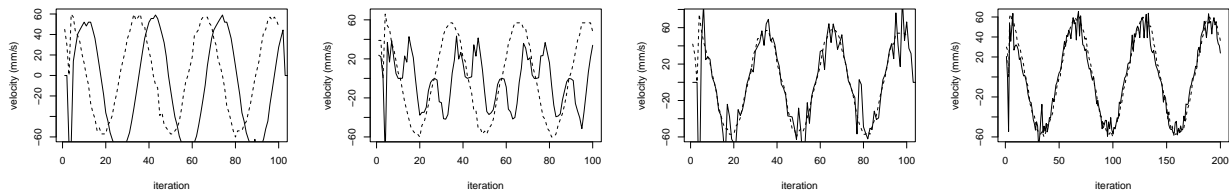
Figure 3: Results of the four methods tested: method 1 on the far left, method 4 on the far right.

4 Conclusion

We have presented different methods that allow us to increase the level of interaction (synchronization-imitation) thanks to biologically plausible processes. These processes are simple and easy to implement.

If we want to synchronize a dance, velocity detection is very useful. However, the detection of position is more useful to follow a moving target. We see also that velocity detection can help to anticipate the target tracking by anticipating. The robot could learn to anticipate the position using velocity perception for best tracking. Studies such as Hofsten and Rosander (1996) and Richards and Holley (1999) investigate how babies develop the capacity of smooth tracking with the same kind of protocol. Since we have access to the velocity and not only to the area of movement, we should be able to make the robot learn what is associated with its own movement. Hofsten and Rosander (1996) also show that babies progressively develop a better coordination between the movement of the eyes and the head. We could use this work as inspiration to reproduce this phenomenon with robots.

Further work could try to make this architecture more biologically realistic, allowing the robot to integrate or to predict the consequences of its own movement and apply this method to the synchronization and coordination problem. Therefore, we will focus our work on the learning of the perception-action mapping inspired by the psychology studies of Prinz (1997), which seem to fit well our robotics approach.

Acknowledgments

References

P. Andry, P. Gaussier, and J. Nadel. From sensorimotor development to low-level imitation. In *2nd Intl. Wksp. on Epigenetic Robotics*, march 2002.

P. Gaussier, S. Moga, JP. Banquet, and M. Quoy. From perception-action loops to imitation processes. *Applied Artificial Intelligence*, 1(7), 1998.

E. Hatfield, J. Cacioppo, and R. Rapson. *Emotional contagion*. Cambridge university press, 1994.

C. von Hofsten and K. Rosander. The development of gaze control and predictive tracking in young infants. *Vision Research*, 36, 1996.

E. von Holst and H. Mittelstaedt. Das reafferenzprinzip. wechselwirkungen zwischen zentralnervensystem und peripherie. *Naturwissenschaften*, 37, 1950.

A. Johnston, C.P. Benton, and M.J. Morgan. Concurrent measurement of perceived speed and speed discrimination threshold using the method of single stimuli. *Vision Research*, 39, 1999.

W. Prinz. Perception and action planning. *European journal of cognitive psychology*, 9(2), 1997.

J.E. Richards and F.B. Holley. Infant attention and the development of smooth pursuit tracking. *Developmental Psychology*, 35, 1999.

L. Steels. Mathematical analysis of behavior systems. In IEEE Computer Society Press, editor, *From Perception to Action Conference*, Lausanne, Switzerland, 1994.