Romeo and Juliet: an infrared search system

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***Abstract*— The aim of this paper is to describe a comprehensive system of two robots that are able to localize each other in real-time using an infrared communication. The robots start from a distance between 10 and 50 cm and they do not know each other's position. The can only communicate by a half-duplex channel. The robots use a simple localization algorithm to meet.**

***Index Terms*— Optical communication, optical position measurement, mobile robots, distributed algorithms.**

I. Introduction

We describe the bio-inspired behavior of two entertaining robots, that are built to perform an artificial dance. The young visitors of the scientific exhibition LUS [1] gave them the nicknames Romeo and Juliet. These are made of Lego bricks, adopting the RCX 2.0 [2]-[4] of Lego Mindstorm series. From a technical point of view, we consider the robots in an environment where they move on a limited plane area. The task of Romeo is to reach Juliet. The robots communicate with each other without the help of infrastructure and other facilities of the environment. Moreover, the communication channel is half-duplex. These constraints could be interesting in the study of pioneer exploring robots. This paper describes the robots' characteristics, considering in particular the adopted algorithm.

II. The robots Romeo and Juliet

A. Romeo

Romeo is a typical thin three-wheeled robot (Fig. 1).

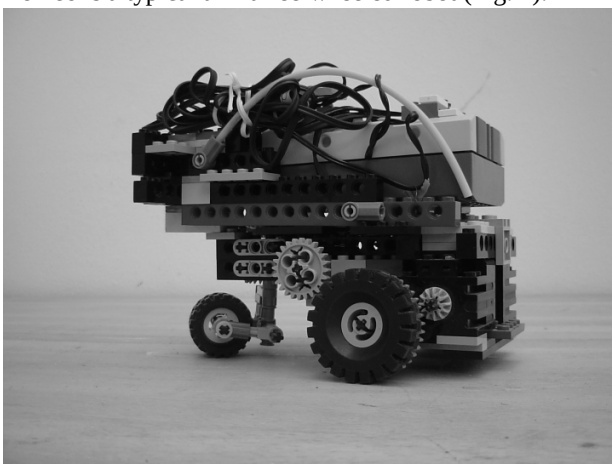

Fig. 1 The robot Romeo.

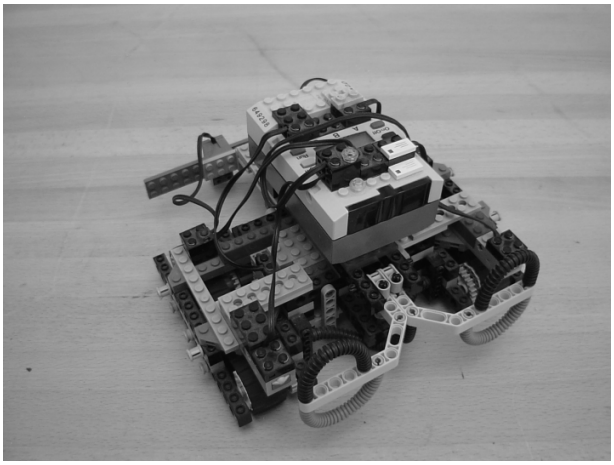

Fig. 2 The robot Juliet.

It has two wheels driven by independent motors. This robot communicates by an embedded infrared port at a transmission rate of 2400 bps.

B. Juliet

Juliet (Fig. 2) is a robot with two independent tracks and has a somewhat "matronly" shape. She has two light sensors to recognize the various light beams that are naturally reflected by the floor. These sensors acquire data about the floor portion behind them in order to prevent the robot from moving to dangerous areas.

She perceives the contact with the other robot by means of two switched whiskers. The way we connected the switches realize an OR logic function because both the switched whiskers act as one sensor. We adopted this solution because the RCX lacks sensor ports.

This robot communicates in the same way as Romeo.

III. Description of the robots' behavior

The two robots are placed on a plane surface, usually at a distance of about 50 cm, as illustrated in Fig. 3. The starting directions of both robots are random.

At first, Juliet memorizes the properties of the floor below the sensors, thus identifying the safeness area. We compare this process to the imprinting process. We assume that her initial position is in the safeness area. Then, she spins and waits for Romeo actively: she sends out infrared signals that we compare to appealing looks.

When Romeo is switched on, he looks around for Juliet so, that they are "looking for each other". When their looks meet, they stop for a moment (the time of a "smile") and Romeo

ROBOCOMM 2007, 14th – 16th Oct 2007, Athens, Greece.
Copyright © 2011 – 2012 ICST
ISBN 978-963-9799-08-0
DOI 10.4108/ICST.ROBOCOMM2007.2132

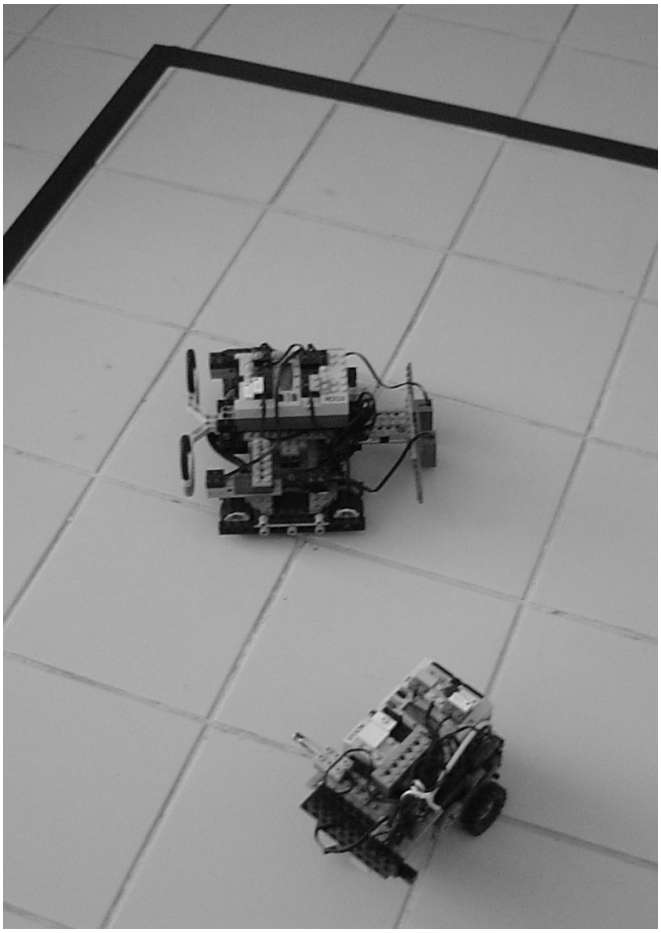

Fig. 3 The SA search phase.

goes towards Juliet, "willing to kiss her". When they meet, he stops and she moves back for a maximum of twenty centimeters. If she moves out of the safeness area before stopping and being reached by Romeo, the algorithm ends. Otherwise, she comes back to Romeo and the dance restarts.

IV. The Algorithm

The algorithm is distributed: the robots work in parallel and they act as autonomous units (Fig. 4 and Fig. 5). The pros and cons of this architecture are those typical of this kind of structure (distributed algorithms). Since the communication channel is not completely reliable, the algorithm must take account the transmission errors and make the two robots behave accordingly: even if only one error occurs, the two robots restart from an appropriate state as explained below.

We identify two phases for the transmission protocol. The first, that we call SA, is divided into two parts because the communication channel is half-duplex: the search and the approach. The second phase, that we call M, controls the meeting of the robots.

A. The SA search phase

In this phase, Juliet spins sending "Hello!" messages lasting 200 milliseconds. Every message is coded with the integer value 0.

Then she waits for Romeo's answer, the waiting time lasting 200 ms. In the meantime, Romeo is only ready to receive messages, and does not send out any signal, in order to keep the communication channel free. He is spinning too, in order to arrange himself in a straight line with respect to Juliet.

When Romeo receives the "Hello!" message, he stops spinning (he stops all the motors) and sends his 200-ms long "Hi!" message. This is coded with the integer value 1. Then Romeo waits for Juliet's answer.

At this step of the algorithm, we are sure of the two robots alignment due to RCX infrared directionality.

The transmission rate of the infrared ports is 2400 bps, and they work according to the RS232 serial port standard: 11 bit are necessary for each transmitted byte. In this transmission mode, each message can contain one of the 256 transmittable symbols, so that the transmission time of each message is circa 4,584 ms. This implies that during the 200-ms transmission time (e.g. the "Hello!"), about 43 messages are sent. This allows a good alignment probability.

B. The SA approach phase

Juliet starts this phase when she has received the "Hi!" from Romeo. Now they are aligned, so that they can stop spinning. Juliet transmits her 200-ms "Hello!" message and waits for an answer within 200 ms. If she receives the message, she transmits another "Hello!"; otherwise, she starts the search phase.

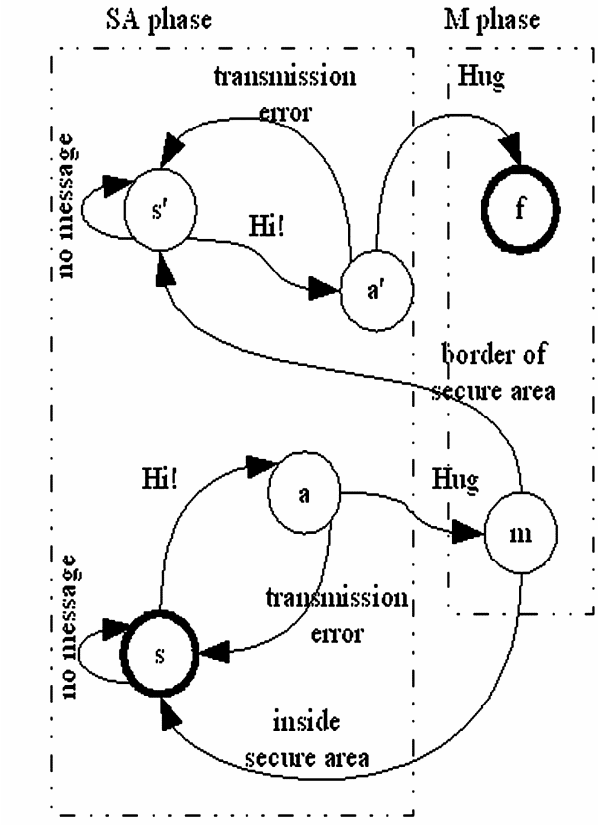

Fig. 4 Juliet's protocol.

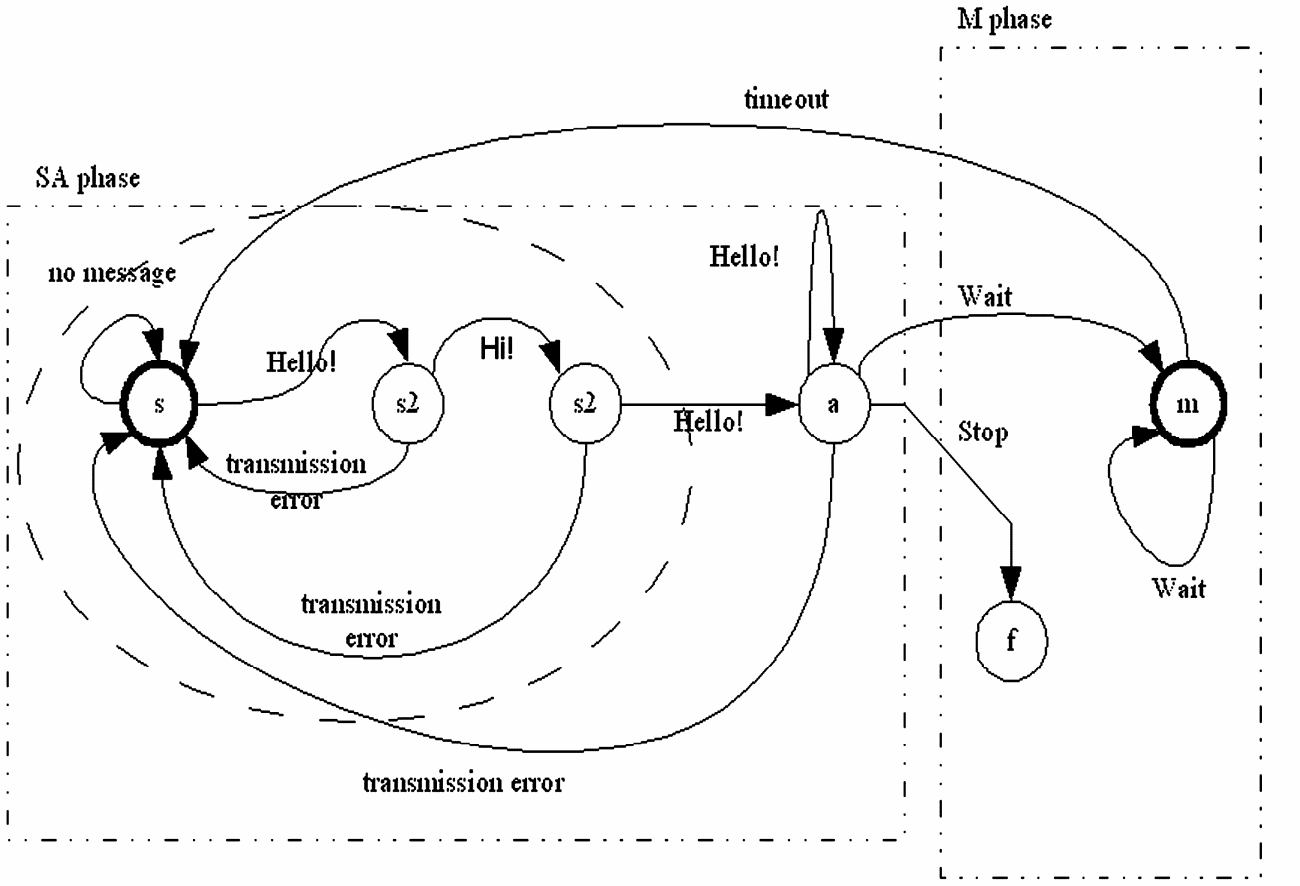

Fig. 5 Romeo's protocol.

Romeo starts this phase when he receives the "Hello!" from Juliet as an answer to his own "Hi!". Now, he goes toward Juliet and transmits his 200-ms "Hi!" message and waits for an answer within 1000 ms. When he receives the message, he transmits another "Hi!". Otherwise, he changes his phase into the search phase.

This continuous exchange of messages ensures that the two robots maintain the alignment while Romeo is approaching Juliet.

In order to describe the "Romeo and Juliet algorithm" let us describe the states of the two robots (Fig. 4 and Fig. 5). Juliet switches from states s and *s'*, respectively, to *a* and *a'*. Romeo switches from the state *s* to *a* through *s1* and *s2*, according to the rules of the SA phase. In the M meeting phase, each robot can assume two different states: the *m* and the *f*.

A. The M meeting phase

Romeo goes toward Juliet and hits her switched whiskers softly. This goal is achieved by means of their hardware and software.

When Juliet perceives that Romeo has hugged her while she is in the *a* state, she switches into the meeting *m* state. If she perceives the hug while she is in the *a'* state, she switches into the final *f* state.

In the first case, she stops all the other activities and sends "Wait" messages (codified with the value 2) to Romeo, continuously, while going back. If she goes back for about twenty centimeters, she "changes her mind" and goes towards Romeo and changes her state into the search *s* state. Otherwise, she reaches an unsafe area and changes her state into *s'*.

In the second case, she sends the 200-ms "Stop" message and waits for an answer within 200 ms. If she receives the answer "Here I am", she switches off.

When Romeo (into the *a* state) receives the first "Wait", he changes his state into the meeting *m* and stops for 500 ms. He remains in this state until he receives a "Wait". After this time, he switches into the *s* search state.

When Romeo (into the *a* state) receives the "Stop" message, he answers sending a "Here I am" message lasting 1000 ms, and then switches off.

V. CONCLUSION

We presented this experience because we think it is interesting that toy robots can couple using simple mechanism.

We are using them as prototypes to obtain better

performances in the future with new interactive robots, which will perform in dances that are more complex.

Our young visitors performed a number of successful experiences with this two-robot system, and we feel that these experiences are an effective test of the reliability of the “Romeo and Juliet algorithm”.

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