Directing Mobile Robot Roaming Path Based on Skinner Automation

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Abstract

Ideally, a metric map is constructed prior to launching a mobile robot. It is an estimated zone—robot’s roaming area and is a reference topology that defines robot’s constraints. This work suggests relational models between a human operator and a robot based on Skinner automation model. The relationship is an idea where an operator instructs a robot to follow an expected path. Four light-dependent robots of similar control circuit design were designated as followers while operators were the masters. A unique path was drawn on a piece of graph paper. The robots were instructed to follow the light source directed by the operators while the operators themselves tried to direct the light according to the proposed path within the roaming zone. There were significant deviations between the expected paths proposed by the operator, and the actual paths made by the robots. The relationships between human thought and the robot’s conception did not match. It was tedious to instruct a mobile robot that relied on the intensity and direction of light. While the machine’s processing delay was the main issue, there were also problems contributed from the machine’s subsystems. The robot must be a perfect machine to achieve an ideal human-robot relationship.

***Keywords**:* metric map, mobile robot, relational model, Skinner automation.

1. Introduction

Ideally, a metric map is constructed prior to launching a mobile robot. It is an estimated zone where the robots are expected to move around, hence a roaming area. It is a reference topology that defines robot’s constraints, and is one of the important criteria in mobile robot locomotion, navigation and identification [1].

Usually, the dynamics of a mobile robot system is not considered in the control methods. Therefore, control designers avoid considering the effects of weights and forces in deciding the most efficient algorithms. In fact, mobile robots are non-holonomic systems, which mean their dynamical system of equations is non-integrable. Nevertheless, the objective of a kinematic controller is to follow a trajectory described by the robot’s position and velocity profiles as a function of time.

The robot trajectory or path can be divided into edges and segments of circles. Edges and segments of circle form details on a path. Using this information, the control designer will be able to build proper kinematic control algorithms. However, this approach had some drawbacks because it is not straightforward to pre-compute a feasible trajectory. In addition, the robot may not be able to adapt or correct the trajectory if there are dynamical changes to the environment. The actual trajectory performed by the robot may not be smooth. Mobile robot applications can range from an offshore inspection [2] to a military weapon system. The advances of robot technology have to do with the advances of human thinking.

Even the most complex intelligent algorithms embedded into the robot's processor, it will still require some sort of human interventions. This work, nevertheless, suggested the relational models between a human operator and a robot. The scope, however, exclude the notions of artificial intelligence.

2. Background

2.1 Common Approach

Approaches to mobile robot locomotion, navigation, and identification vary. Yamada et al. [3] worked on a mobile robot that tracked target through a self-window that extracted the color information. Luo et al. [4] used a pre-defined line based map and a laser ranger finder to detect the environment. This approach applied map-matching scheme that scanned range data. Landmark, such as the helipad, was used as a unique feature that the autonomous helicopter could recognize and land on the spot [5]. It navigates from an initial point to the final point in a partially known land. The advantage of tracking target through a self-window is that the robot does not require pre-defined features to track on. On the other hand, using a pre-defined line map could deter the robot from making a wrong path but the robot has a limited roaming area.

There are two sub modules in the path planning algorithm: one is global path planning that applies visibility graph; another is local path planning that uses potential field method to avoid obstacles [6]. Fuzzy logic may be applied in a sub module algorithm to avoid obstacles and to minimize zigzag motion on the path [7]. Path planning is a necessity in deploying a mobile robot. Having an appropriate map allows the designer to write proper algorithms and inclusion of intelligence would permit the robot to take decisions, hence autonomous. Most mobile robots operate at a low speed. In a low-speed mode, a mobile robot can follow curvatures with ease. For a high speed robot, however, following curvatures are difficult because the motor controls could not cope with the momentums. To overcome this problem, the speed must not change rapidly and the curvature of the motion is constant [8].

2.2 Skinner Automation

The Skinner automation (SAuto) is built for modeling and formalizing the neural mechanisms of operant conditioning. Applications of SAuto in mobile robot controls were discussed extensively in [9], [10, 11]. The SAuto is a 7-tuple defines in Eq. (1).

$$\left.\begin{array}{l}\text{SAuto} = (t, S, O, E, R, F, SA) \\ \text{where} \\ t \in \{0,1,2,\cdots\}\text{: the discrete time,} \\ S\text{: the set of states,} \\ O\text{: the set of operants,} \\ E\text{: the energy unit,} \\ R\text{: the set of reinforcers} \\ F: S \times O \to S\text{: the state transition} \\ \qquad\qquad\text{process, and} \\ SA\text{: the Skinner algorithm}\end{array}\right\} \quad (1)$$

The discrete time (t) is to discretize the process of operant conditioning for digital computing and to mark the simultaneity of cause and effect. The energy unit (E) represents an internal energy function that assigns each state (S) an energy value or an energy cost. In effect, the internal energy function represents the propensity or tropism of the SAuto.

3. Methods

3.1 Relational Model

3.1.1 Definition I

A mobile robot (Π) is a machine that moves by the control of electrical motor (μ). The motor links to a wheel (ω) through a mechanism. The Π applies differential drive that permits forward movement, turn-right, and turn-left by specific controls of the events of wheel rotations.

3.1.2 Definition II

A controller (Ξ) is a blend of electronics and electrical components and devices that upon energized it will function according to the pre-determined tasks. The Ξ consists of a number of resistors(ρ), transistors(τ), light emitting diodes (δ), and light dependent resistors(λ). The electrical potential (ε) energizes Ξ.

3.1.3 Definition III

The Π has at most three sequences of movement: Forward(Φ), Turn-right (TP), Turn-left $(\mathrm{T\Lambda})$.

3.1.4 Definition IV

The operator (O) is human who is has been trained to instruct Π. The O will hold a light source $(\Lambda\Sigma)$.

3.1.5 Lemma I

Let the machine be the fusion of the mechanical structure $\Pi[\omega]$ and the controller $\Xi[\mu,\rho,\tau,\delta,\lambda,\varepsilon]$. The machine will function as required if the following properties are met:

i) ω is fixed correctly and is the right size,
ii) μ, ρ, τ, δ and λ are properly connected following the right circuit, and they are the right components and devices based on the circuit specifications, and
iii) ε is supplied to the machine and is at the right voltage and polarity.

3.1.6 Lemma II

Let O be the master and Π be the slave. The master would instruct the slave so that the slave would execute events of movement such that

$$\left.\begin{array}{l}\Phi \text{ iff } \left(\Lambda\Sigma \to \{\lambda_1 = \lambda_2\}\right) \\ +\mathrm{T\Lambda} \text{ iff } \left(\Lambda\Sigma \to \{\lambda_1 > \lambda_2\}\right) \\ +\mathrm{TP} \text{ iff } \left(\Lambda\Sigma \to \{\lambda_1 < \lambda_2\}\right)\end{array}\right\} \quad (2)$$

3.1.7 Proposition

If the O focuses $\Lambda\Sigma$ to either or both λ then Π will follow accordingly.

3.1.8 Skinner Representation

Therefore, the Skinner representation for the system may be written, by assuming the 7-tuples exist, as

$$\text{SAuto} = \left(\Pi[\omega], \Xi[\mu, \rho, \tau, \delta, \lambda, \varepsilon]\right) \quad (3)$$

3.2 Setup

Four light-dependent robots, with a similar electronic control circuitry were built. The control circuit, shown in Fig. 1, provided the robot with a differential drive that functioned according to the level of light detected by the light dependent resistors (LDRs). Therefore, robot maneuverability would depend on the direction of lights made by a human operator, seen in Fig. 2.

The robots were the followers while the operators were the guide. For individual robot, it was a master-slave relationship where the master was a human. The relationship between the operator and the robot was defined by an idea where the operator would propose a path, and the robot would need to follow the path, with its capabilities, by reading the instructions given through light intensities.

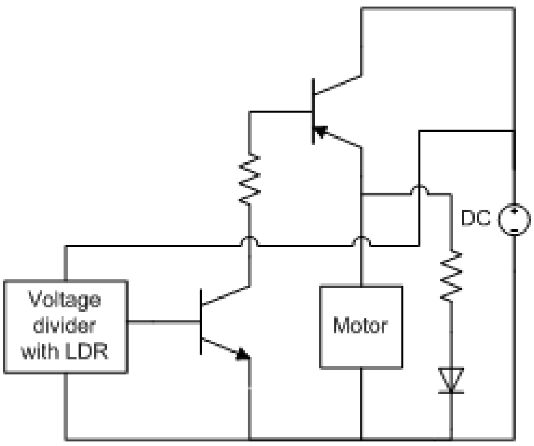

Fig. 1 The controller for the robot.

A path was drawn on a piece of A3 size graph paper. The proposed plane coordinates, in millimeters, were recorded and these represented curvatures of a unique path. There were ten points marked upon the paper; point-0 was the initial and point-9 was the end. The selection of the coordinates was mere estimation. There was no specific approach to generating these points. On the proposed path were points that defined the roaming zone.

Fig. 2 The robots in action, roaming on a predefined path on a graph paper. Robot-1, Robot-2, Robot-3, and Robot-4 arranged from the top-left to the bottom-right, respectively.

4. Results and Discussions

4.1 Results

There were significant deviations between the expected paths drawn by human operators, and the actual paths made by the robots. The predefined paths and the paths made by the robots are shown in Figs. 3–6. The dotted-blue curve represented the actual path, whereas, the solid-red curve represents that expected path.

Path made by Robot-1 showed the largest variant among all the paths. It followed by Robot-4 and Robot-2, whereas the path made by Robot-3 seemed to superimpose the expected path. Robot-1 and Robot-2 exhibited sharp turned along the path. Robot-3 and Robot-4, on the other hand, maneuvered smoothly along the path. Robot-1 and Robot-2 had a front differential drive, whereas Robot-3 and Robot-4 had a rear differential drive.

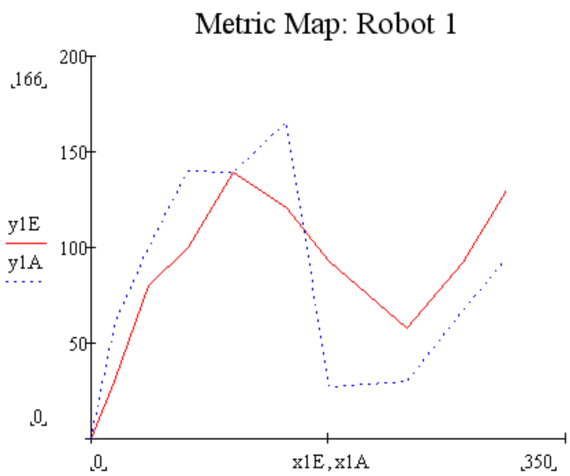

Fig. 3 The predefined path proposed by the master, and the actual path made by the slave—Robot-1.

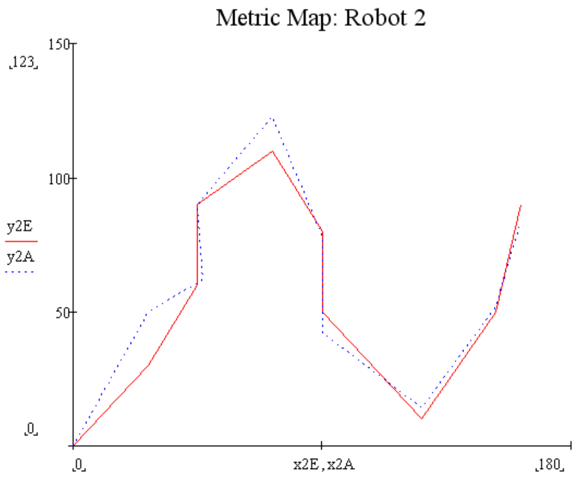

Fig. 4 The predefined path proposed by the master, and the actual path made by the slave—Robot-2.

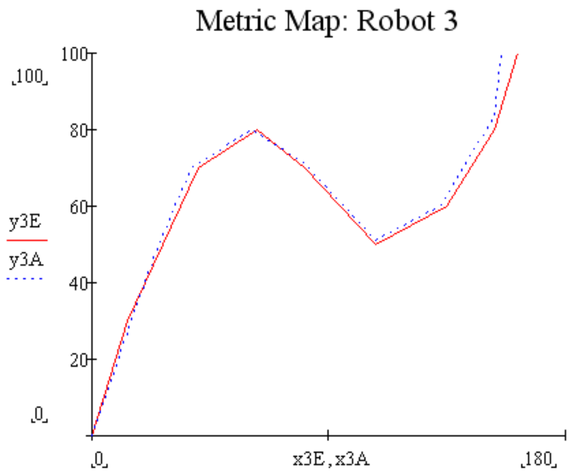

Fig. 5 The predefined path proposed by the master, and the actual path made by the slave—Robot-3.

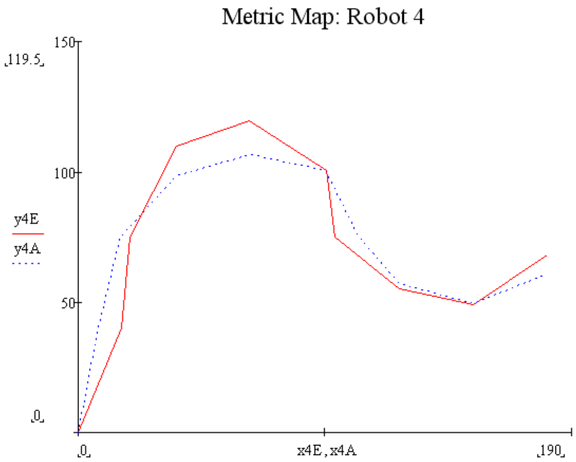

Fig. 6 The predefined path proposed by the master, and the actual path made by the slave—Robot-4.

4.2 Discussions

The relationships between human thought and robot's conception did not match completely. This was especially true for human-and-Robot-1, human-and-Robot-2, and human-and-Robot-4 pairs. Uniquely, human-and-Robot-2 pair seemed to communicate almost perfectly when executed the required tasks— to follow the preplanned path.

It was observed that a front and a rear differential drive did affect robots' maneuverability. For a front different drive, the robots quickly responded to a (TP) or $(\mathrm{T}\Lambda)$ instruction. As a result, it performed a sharp turn when instructed to turn. Conversely, for a rear differential drive, the robots responded slowly to a turn instruction. These events, however, would depend on the speed setup on the robots' controller that drove the motor, (μ). So that master-slave communication and SAuto for the mobile robots experimented in this work may be written, respectively, as

$$\left.\begin{array}{l}\Phi \text{ iff } \left(\Lambda\Sigma_{\text{PRECESSION}} \rightarrow \{\lambda_1 = \lambda_2\}\right) \\ +\mathrm{T}\Lambda \text{ iff } \left(\Lambda\Sigma_{\text{PRECESSION}} \rightarrow \{\lambda_1 > \lambda_2\}\right) \\ +\mathrm{TP} \text{ iff } \left(\Lambda\Sigma_{\text{PRECESSION}} \rightarrow \{\lambda_1 < \lambda_2\}\right)\end{array}\right\}$$

$$\text{SAuto} = \left(\Pi_{\text{FRONT + REAR}}[\omega], \Xi[\mu_{\rightarrow\text{SPEED}}, \rho, \tau, \delta, \lambda, \varepsilon]\right)$$

5. Conclusions

Master-slave relationships between humans and machines have been researched for decades. The problematic about the relationships is that machines are incapable of reasoning. Although there are progressed in machine intelligence, still the issue is the delay in the machine's responses to instructions. . It was tedious to instruct a mobile robot that relied on the intensity and direction of light. While the machine's processing delay was the main issue, there were also problems contributed from the machine's subsystems.

This work experimented with simple machines with basic control circuitry; the machines needed to respond to an instruction based on the operator's movement rates. The movement rates were the inputs for the process that controlled the rates of the direction of the transmitting light. The light receivers would process the collected radiations and performed a programmed task. There was a processing delay for the robot to respond. The delay issue could be solved by electronic adjustments. In addition, the actuators' speed that caused the machine to move either as desired or otherwise. Again, the actuators' speed issue could be solved but there existed the mechanical balancing and alignment issues. In short, the system is interrelated and is defined in Eq. (3). Therefore, the robot must be a perfect machine to achieve an ideal human-robot relationship.

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