Method and Effect of Preliminary-Announcement and Display for Translation of Mobile Robot

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Abstract

This paper discusses the preliminary-announcement and display method of the action and intention which is carried with a robot which moves in a human-coexisting environment. It is pointed out that two kinds of information of the speed of motion and the direction of motion are important on the preliminary-announcement and display of the action of a mobile robot. The method by using blowout is proposed to tell surrounding people about these two kinds of information simultaneously. Especially in translation, the preliminary-announcement and display method of the speed of motion is examined using a software simulation concerning the case that a robot is equipped with blowout, lamp, or no apparatus. Consequently, the effectiveness of the preliminary-announcement and display using blowout and the importance of information about the speed of motion are confirmed. Moreover, it is considered that the cause of the gap between the recognition of human and the actual motion includes the forestallment error, the reaction delay, and the handling delay towards the change of speed.

1. Introduction

Recently, the motion space of a robot and human being is becoming overlapped. Automatic vehicle which conveys goods in a factory and conveyance robot which carries a meal and/or a chart in a hospital are examples. On the other hand, network technology is integrated with robotic technology [1]. For example, the remote appreciation system is now progressing in research and development. This system is for physically handicapped people who cannot go out according to aging or unexpected accident. Those people would be able to appreciate in an actual fine-arts hall and/or museum by operating a mobile robot remotely. When this remote appreciation system is used practically, the motion space of common people and a robot will come across more frequently. The informational affinity between human and a robot will become more important when a robot works and acts in such a human-coexisting environment.

This study examines the informational affinity so that a following action and/or intention of a robot are announced and transmitted beforehand to human. In this paper, the method to announce and display preliminarily the action of a mobile robot are discussed and it is examined using computer simulation. We would like to propose a simple and intelligible way as much as possible for surrounding people.

This paper firstly points out the importance of two kinds of information, the speed of motion and the direction of motion, on preliminary-announcement and display of action of a mobile robot. Then we propose a method using blowout to tell these two kinds of information simultaneously. Furthermore, the preliminary-announcement and display about translation of mobile robot is examined in detail with three cases that the robot has blowout, lamp, and no apparatus, respectively.

2. Method of Preliminary-Announcement and Display

2.1. Conventional Method

Others' action and intention are predicted using non-verbal-information, such as body language, among human beings. For example, a person who passes through in bustle anticipates other's direction of motion and the speed of motion considering the direction of looking, the direction of leg stepping forward, the posture of arms to swing, etc. This is because people share the knowledge and information about action to each other as common sense such that a person moves in the direction to which the body is turned. So we can behave based on the recognition. For example, he/she will be away from the other's path, or he/she will stop and wait until the other passes completely. However in general it is difficult for human to predict the action and intention of a robot. One reason is it is difficult for common people to imagine the maximum speed and/or the maximum power which a

robot can output from its appearance.

Conventional mobile machine only tells its approaching. Automatic vehicle and conveyance robot will light, blink and rotate a warning lamp, and/or they will play a melody through a speaker. In such cases, the information transfer means is equipped with the vehicle. On the other hand, when a train approaches a station, a display lamp will be lighted up and/or some guidance voice will be said. In this case, the information transfer means is installed at the surrounding facilities. In any conventional mobile system, unspecified surrounding people are expected to keep away from the path of machine. And the transferred information is too simple and insufficient on affinity between human and machine. Moreover in the case of remote-operated mobile robot, a robot acts in unspecified position and direction and it does not move on the path decided beforehand. Then it is not practical that some announce-and-display apparatus is installed to every facilities beforehand.

2.2. Method using Blowout

Since human and a robot do not necessarily share the same common sense, robot has to have a certain method for preliminary-announcement and display of its action for human. The kinds of information to announce and display must be as few as possible to become acceptable for human. Concerning the mobile robot, the direction of motion and the speed of motion are regarded as the most important. At least these two kinds of information must be preliminary-announced and displayed by some method which is sensible and easy to understand for human. We propose a method using "blowout" (Fig. 1 and 2) [2]. Blowing air into a cylinder extends blowout and stopping the blowing rewind it from the top. The blowout is set up horizontally on a turntable. The direction of the blowout shall display the direction of motion of a mobile robot, and the length of the blowout shall indicate the speed of motion. Human seems fit in with that the lengthening object describes faster speed and the shortening object indicates slower speed. Those are looking easy to understand and agree in human's common sense.

3. Software Simulation

A software simulation has been developed to confirm the effectiveness of announcing beforehand and displaying the direction of motion and the speed of motion of a mobile robot by using blowout. This chapter explains the details of the computer simulation and the evaluation method.

3.1. Development of Simulator

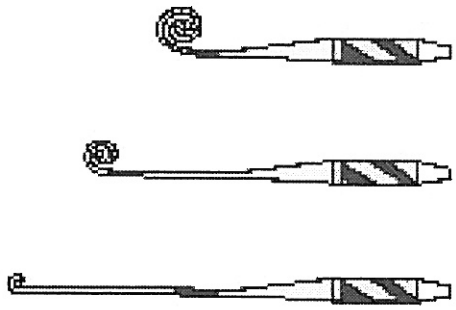

Fig. 1 Blowout

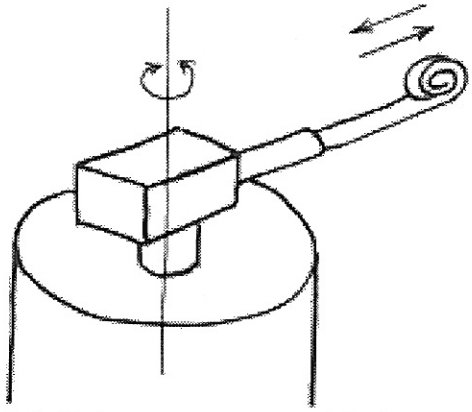

Fig. 2 Preliminary-announcement and display apparatus

Simulation software is developed on a Windows-PC using Visual C++ 6.0, OpenGL, and DirectX. A mobile robot moves on a horizontal two-dimensional plane in a three-dimensional virtual space (Fig. 3). The form of the mobile robot is a rectangular parallelepiped, and the front half and the rear half are displayed in different colors so that the front might be known. We are preparing a non-holonomic type mobile robot in real world. It can translate towards any directions and can rotate on a point. However in simulator, we decided that the robot should turn so that its front coincides with the direction of motion when the robot translates. We want to investigate whether human being who lives together can predict the motion of the robot which moves about at random on the plane. The position of preliminary-announcement and display apparatus and the viewpoint of human can be changed easily and its efficiency can also be examined immediately because of a software simulation. Moreover when other new preliminary-announcement and display apparatus come into mind, its ability will also be checked easily. Here we compare and examine the efficiency of using blowout, lightning lamp, and no apparatus.

1) Using blowout: Blowout which is set up on the upper surface of the mobile robot is modeled as an arrow which changes its length. The length of the arrow indicates the

speed of motion of the robot and the direction points out the direction of motion (Fig. 3). In the simulation, the robot moves changing the speed at random in three stages: high, middle, and low. The length of the arrow is changed continuously like blowout, so the haft of the arrow is painted in three colors by the range of its length. The robot moves in one of twelve directions in the round at random. The robot always translates after rotating at a fixed speed on a point, since it is set up that the robot can translate when its front coincides with the direction of motion. The direction of the arrow shows the direction to which the robot is going to turn its front.

2) Lighting lamp: The lamp is arranged on the upper surface of the mobile robot, and lighting shows the direction to which the robot is about to turn its front. Twelve lamps should be arranged in the round so that the robot moves in one of twelve directions. Lighting only indicates the information about the direction of motion. The blinking rate and/or the color of lamp may describe the information on the speed of motion. Human may naturally understand that a lamp of bright color or a lamp blinking quickly indicates the fast speed of robot's motion.

3) No apparatus: A person who meets up with a mobile robot cannot decide his/her reaction without some function on preliminary-announcement and display of action of the robot. Conveyance robot reacts variously when detecting some obstacle on a scheduled path. One robot stops and waits until the obstacle is removed, and the other bypasses the obstruction by some patternized program. If a person has a certain amount of experience and he/she reserves some knowledge about the robot such as a history of movement until then, he/she may judge and take some reaction with understanding the peculiarity of the robot and/or using intuition. However person cannot deal with a robot well which he/she meets for the first time.

3.2. Evaluation Method

In order to confirm the effectiveness of announcing beforehand and displaying the direction of motion and the speed of motion of a mobile robot, efficiency is estimated with the error between the recognition of human and the actual motion of robot.

The "mobile robot" moves about at a random speed and in a random direction on two-dimensional plane in a virtual space. A person operates the "operation robot" of a cylinder form by using a joystick so that the operation robot may not be detached from the back of the mobile robot. Fig. 3 shows a virtual space from the viewpoint of the camera which is set up on the upper surface of the operation robot virtually. A person is pursuing the mobile robot with this view. The position and direction of both robots are recorded. The path of the "operation robot"

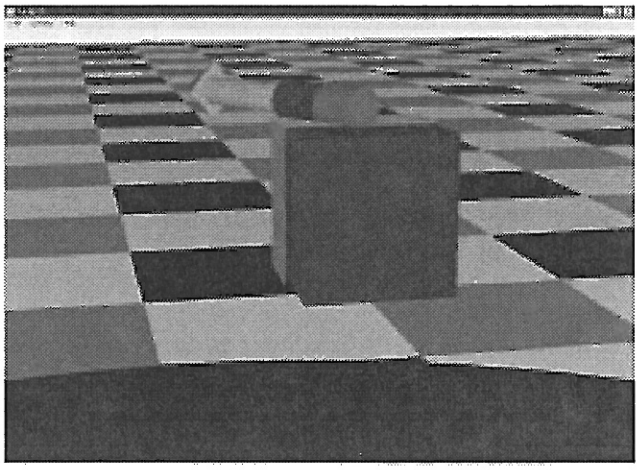

Fig. 3 Simulation of preliminary-announcement and display using blowouts

reflects the recognition of human and the path of the "mobile robot" shows the actual motion of robot. Therefore, the efficiency of preliminary-announcement and display of action of a robot and the efficiency of each method can be evaluated by examining the gap between the "mobile robot" and the "operation robot".

4. Basic Examination in Translation

This chapter describes the result of a basic examination about preliminary-announcement and display in translation of mobile robot. It is very difficult to examine the speed of motion and the direction of motion simultaneously which should be preliminary-announced and displayed when a robot moves within a two-dimensional plane. Here we examine the method of preliminary-announcement and display about the speed of motion in translation. Definitely, the method and the timing to announce and display the speed of motion are examined using software simulation.

4.1. Experimental Setup

Three-dimensional virtual space is shown to the subject person with the viewpoint of looking down at a horizontal plane where a "mobile robot" and an "operation robot" move, in the experiment of this chapter. The "mobile robot" (blue square in Fig. 4 and 5) moves along a certain straight-line changing speed at random which is not only positive value but also negative. Therefore the mobile robot moves about right and left on the straight-line. The "operation robot" (yellow circle in Fig. 4 and 5) which moves by joystick operation of the subject person moves along a certain straight-line which is parallel to the straight-line for mobile robot. The subject person moves the operation robot so that it may stand in line vertically

with the mobile robot as much as possible. The position of the "mobile robot" and the "operation robot" are recorded. The method and the timing of preliminary-announcement and display are evaluated by comparing the position gap between the mobile robot and the operation robot.

The speed of motion of the mobile robot is set in three stages. The operation robot is controlled in speed command mode using joystick. The inclination angle to right or left of the joystick determines the speed of the operation robot. The speed of the operation robot when inclining joystick to the maximum is corresponded with the maximum speed of the mobile robot. The subject person is a 22-year-old university student in the following experiments.

4.2. Method and Details of Preliminary-Announcement and Display

1) Using blowout: Blowout is set up on the upper surface of the mobile robot (Fig. 4). The blowout is modeled as an arrow which points out right or left and changes its length. The length of the blowout is changed into three stages, since the speed of translation of the mobile robot is also settled in three stages. Time after preliminary-announcement and display of the following action by blowout until the mobile robot translates can be set into every 0.2 seconds from 0 to 2.0 seconds.

2) Lighting lamp: Two sphere lamps are set on the right and the left of the upper surface of the mobile robot (Fig. 5). The robot can preliminary-announce and display the direction of motion to which the robot is going to move only by showing the sphere. As mentioned in the previous chapter, the information on speed of motion can be added by changing the blink rate and/or its color.

4.3. Exp. 1: Method of Announcement

Fig. 6 - Fig. 8 show a result of experiment of using blowout, lighting lamp, and no apparatus. The vertical axis indicates the position of robots and the horizontal axis expresses the progress of time. The thin line shows the locus of the mobile robot and the thick line shows that of the operation robot. Position of robots is measured in the basic coordinate system to model three-dimensional virtual space. The data is recorded for 30 seconds in each trial. Fig. 6 is a result in the case that the following action is announced 1.0 seconds before the actual action by using blowout. Fig. 7 is a result in the case that the following action is announced 1.0 seconds before the actual action by lighting lamp. In this case the lamp neither blink nor change its color so it only presents the direction of motion. Fig. 8 is a result in the case without apparatus to announce and display.

The operation robot can follow the mobile robot almost correctly when the robot preliminary-announces its action

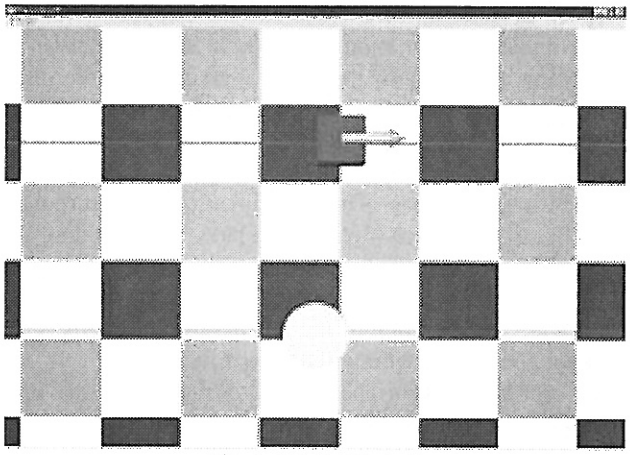

Fig. 4 Using blowout

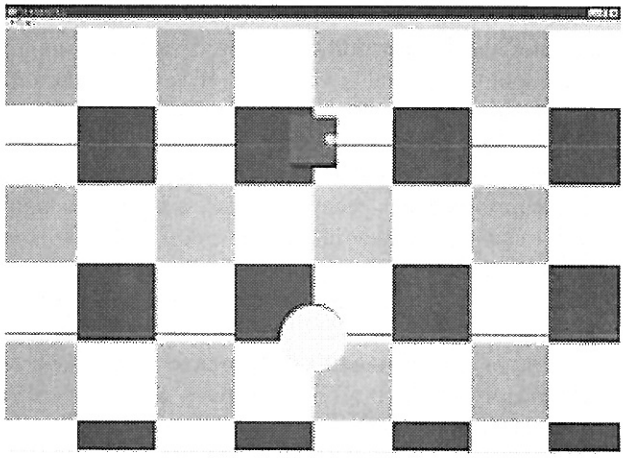

Fig. 5 Lighting lamp

by using blowout (Fig. 6). In contrast, delay is observed clearly in the case without apparatus (Fig.8). And in the case of using blowout (Fig. 6), there seems to be a forestallment action. That is, the person predicts the action of the mobile robot considering the announcement so that the operation robot is moved previously. When there is no apparatus for preliminary-announcement and display (Fig.8), the operation robot cannot follow the conversion of direction and the change of speed of the mobile robot, and the motion of the operation robot becomes tottery. In the case of lighting lamp (Fig. 7), the operation robot cannot follow the change of speed of the mobile robot but it can follow well to the conversion of direction. The evaluation index is calculated as an average of position gap, such that the area between two loci is divided by the measurement time of 30 seconds. The evaluation values in the case of Fig. 6 - Fig. 8 are 50.6 in using blowout, 102.9 in lighting lamp, and 335.2 in no apparatus respectively. From these experimental results, the effectiveness of preliminary-announcement and display of action by using blowout is confirmed.

4.4. Exp. 2: Timing of Announcement

An experiment result when changing the timing of the preliminary-announcement and display is shown in Fig. 9 - Fig. 11. The horizontal axis indicates the time after preliminary-announcement and display until the mobile robot translates. The time is changed every 0.2 seconds in the range from 0 to 2.0 second. The measurement time for one trial is 30 seconds. The evaluation index which is shown in the vertical axis is the average of four trials. Fig. 9 is a result in the case that the action is announced by blowout. Fig. 10 and 11 shows a result in the case of lighting lamp. The lamp is only turned on in the case of Fig. 11. In contrast in the case of Fig. 10, the color of lamp is changed so the information on speed of motion is also displayed. The solid line in chart is a secondary approximation curve which shows varying of the evaluation index against the timing of preliminary-announcement.

Comparing Fig. 9 and 10 with Fig. 11, it is obvious that the tracking action becomes exact when the mobile robot announces not only the direction of motion but also the speed of motion. In this experiment, the best evaluation index doesn't seem different between using blowout (Fig. 9) and lighting lamp (Fig. 10). This is because the subject person in this experiment is the developer of this simulation so he has got used to either method. We have to examine separately the method, taking into account of general common sense of human beings, which is easy to understand also for a person who looks at a preliminary-announcement display system for the first time.

The evaluation index increases when the time difference between preliminary-announcement and actual action increases and it approaches to 2 seconds in either method. And the index also increases when the time difference decreases and it approaches to 0 second. However the cause of increasing the evaluation index is different fundamentally. An operator will operate earlier when the time difference is large. If the time difference becomes too much large, the position gap will become large due to a poor memory, operational mistake, etc. To the contrary, when the time difference is small, an operator will pursue afterwards. If the time difference is too small, operation will be late due to the delay of reaction so the position gap will become large. The optimum time difference is around 0.8 - 1.4 seconds when the position gap by forestallment operations becomes small and the position gap by reaction delay also becomes small.

In the case that the lamp is only turned on (Fig. 11), the position gap becomes larger because of the handling delay towards the change of speed in addition to the forestallment error and the reaction delay.

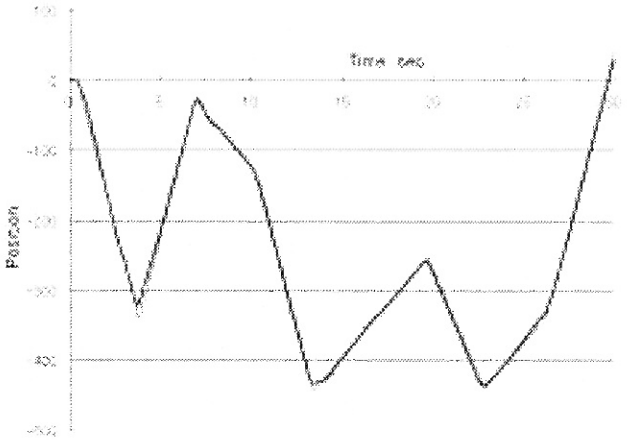

Fig. 6 Using blowout

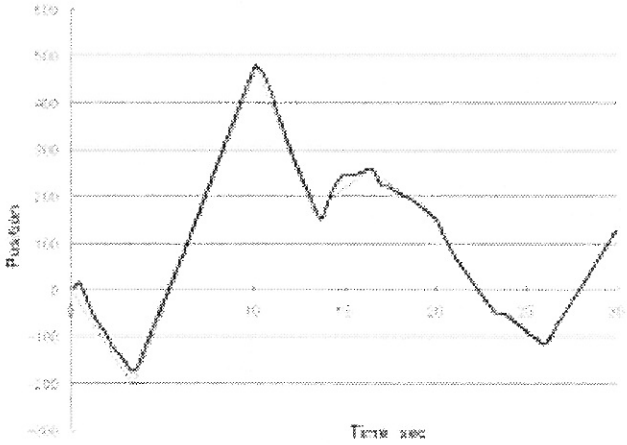

Fig. 7 Lighting lamp

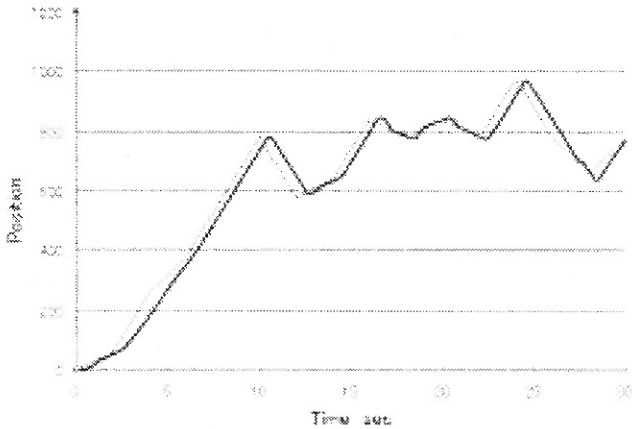

Fig. 8 Without apparatus

5. Conclusion

5.1. Summary

In this paper it has been pointed out that two kinds of

information of the speed of motion and the direction of motion are important on the preliminary-announcement and display of the action of a mobile robot. The method by using blowout has been proposed to tell surrounding people about these two kinds of information simultaneously. Especially in translation, the preliminary-announcement and display method of the speed of motion has been examined using a software simulation concerning the case that a robot is equipped with blowout, lamp, or no apparatus. Consequently, the effectiveness of the preliminary-announcement and display using blowout and the importance of information about the speed of motion has been confirmed. Moreover, it has been considered that the cause of the gap between the recognition of human and the actual motion includes the forestallment error, the reaction delay, and the handling delay towards the change of speed.

5.2. Future Works

The method for preliminary-announcement and display should be advanced in order to become more intelligible for human considering the influence of individuality and collecting data systematically in various conditions such as the timing to announce and the procedure of lighting for the speed of motion, etc. And it should be examined about the revolution of mobile robot. Then the effectiveness of preliminary-announcement and display by using blowout will be examined synthetically concerning a random motion of robot in two-dimensional plane including translation and rotation.

Lighting lamp in this experiment corresponds the blinkers of automobile and motorbike. The importance of information not only on the direction of motion but also the speed of motion has been declared from the experimental result shown here. We would like to propose some new equipment which can display both two kinds of information simultaneously and can be carried in a vehicle.

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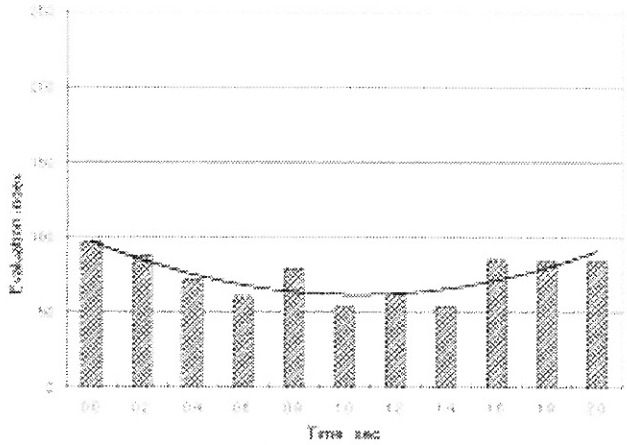

Fig. 9 Using blowout

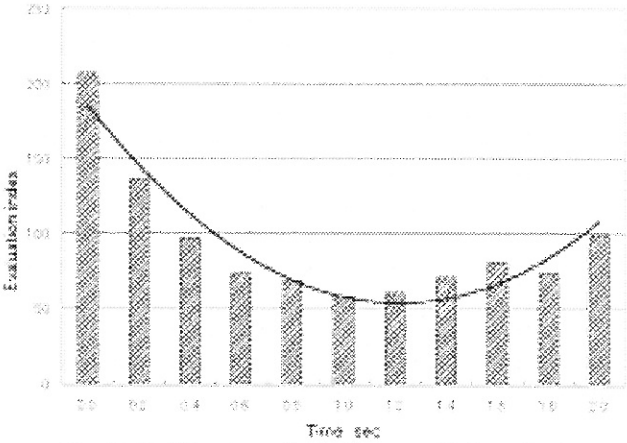

Fig. 10 Lighting lamp (including speed information)

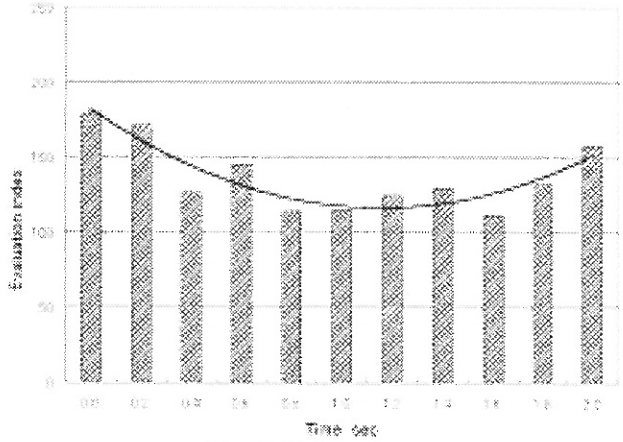

Fig. 11 Lighting lamp

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