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Design and Software Development for Upper Control System of Spraying Robot

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Abstract: **This paper presents a technological solution to develop and change software program for the upper control system of spraying robot. The paper emphatically describes the structural design, the robot upper control system design and software development. The upper control system parts of the spraying robot were achieved by design and program on Delphi programming language that was not tried before. The language is used to create software for controlling upper control system of the robot that included robot arm, path control, rear legs, and spray tank. The effectiveness of the spray robot was checked in a real agriculture field by synchronizing the upper control system and lower control system together, so during the experimental test each upper control system parts were worked successfully in a field. It navigate and move itself and with operator forward, backward, left, right and at an angle from 0-360 degree. The robot had stable and constant velocity and torque. The software control system approach has an advantage of adaptively such that the design and software development for the upper control system of spraying robot approach works perfectly even if an environment is various.**

Keyword: Control System, program, Delphi language, PLC (Programmable Logic Controller), PC (Personal Computer)

1. INTRODUCTION

As farms grow in size, together with the size of the equipment used on them, there is a need for ways to automate processes, before performed by the farmer himself, such as controlling the fields for pests. These tasks are suited for autonomous robots, as they often need many repetitions over a long period of time and over a large area.[1].In most cases, a small agricultural robot would be ineffective in performing farming jobs, as these often need a lot of materials, either to put into the ground, such as seeds or fertilizers or to take from the field during harvest. But when dealing with monitoring and mapping of fields or precision spraying of pesticides, a smaller robot is ideal, as it is more gentle on the crops but also to the ground. [2].Often, there is a need for fungicides and pesticides for the optimal growing of plant and full life of a plant. Automating tasks within the farm will enable the avoidance of hazardous human exposure to pesticide and can increase efficiency and productivity of the farm. For the achievement of the desired conditions, the use of fungicides, pesticides often done by farmers [3].

Among the specific characteristics of pesticide spraying robots are the complexity of their controlling system with the latest programming language; thus, one of the critical problems for the pesticide spraying robots is controlling the upper control system with a new version of programming language by combining each upper control system parts together and synchronizing them with various controllers, such as microcontroller, PLC and so on which is still an open one to be studying . The most important key issue in the development of design and application of spraying robot based on the upper control system are the path navigation process, the arms, and legs directional movement process and the process of controlling the amount and level of pesticide inside the spray tank that can carry chemicals up to 10L.Thus, the way and how they are used is an important role in the domain of controlling an intelligent system.

Manipulating the upper control system is one of the important tasks in the design and software development of spraying robot. The upper control system of the spraying robot parts is path planning, the two arms, the two legs and spray tank of the spray robot. They are often decomposed into path planning, the two arms and the two legs motion control as well as pesticide level control inside the spray tank. Path planning is used to schedule the movement of a spraying robot along the planned path and land area. The two arms and the two legs motion control are used to schedule and guide the movement and direction of the arms and the legs to the required direction depending on the land rows width. Several approaches have been proposed to address the problem of the upper control system of the spraying robot. Because currently Delphi programming language is the latest language tool used to develop software's for controlling the robotic systems, recently some software's has been developed with Delphi programming language for controlling each upper control system alone, but this paper is proposed the Delphi programming language to create and develop software's for each part of upper control system for manipulating them once all together. Robotic systems are capable of some degree of self-sufficiency, navigation, motion control, reliable and functional.

2. OBJECTIVES

There are some objectives need to be achieved to do this project. These objectives will act as a guide and will restrict the control system to be implemented for certain situations using delphi7 programming language:

- To create a software program for monitoring the robot path planning, motion.
- To develop a software program for manipulating the two arms of the robot.
- To develop a software program for manipulating the two rear legs of the robot.
- To create a software program for controlling the spray tank level depending on the upper and lower limit of the spray tank size.

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3. RESEARCH METHOD

Design and software development of upper control System of the spraying robot has the following main approaches. These are:-

(1) Using Borland delphi7.

(2) Using DVP 20 pm PLC MSComm serial communication control and RS485 interface.

The software programs are created on Delphi programming language for each of upper control system parts. The developed programs for all upper control system robot parts are installed in a PC, and then the PC software programs are interfaced with the PLC RS485 interface and MSComm serial port communication. MSComm is needed for input and output data attribute. The input data attribute is used for reading the in receive buffer data while the output data attribute is used for writing the send buffer data. A robot is a machine that can be programmed and reprogrammed to do certain tasks and usually consists of a manipulator. [4]

4. NEWLY INVENTED SOLUTION.

"Software program was taken as a mediator of Control System" as a part of the solution.

(1) The actual concept was focused on to design and develop the software program for the upper control system of the robot using Borland delphi7 which enables them being controlled once at a time in case of the process.

(2) This robot is expected to be capable of driving manually and automatically.

(3) It is useful for reducing wastage of pesticide, time, labor cost, human health hazard, plant pests, and disease.

4.1 Hardware component

(1) Engine.
(2) DVP 20pm Programmable Logic Controller (plc).
(3) 3 Servo Motors with 3 Servo drivers.
(4) Robotic Base.
(5) Three Wheels.
(6) Controller Board.
(7) Wireless remote control device.
(8) Spraying Pump for pesticide spraying.
(9) Spray Tank for pesticide storage.
(10) PC and Touch Screen device.
(11) 7 Linear Actuators.
(12) Spray Nozzles.
(13) Operator seat, Square pipes, and pipes.

4.2 Block diagram

There are three main units:

(1) Input unit.
(2) Sprays and Control Processing unit.
(3) Output unit.

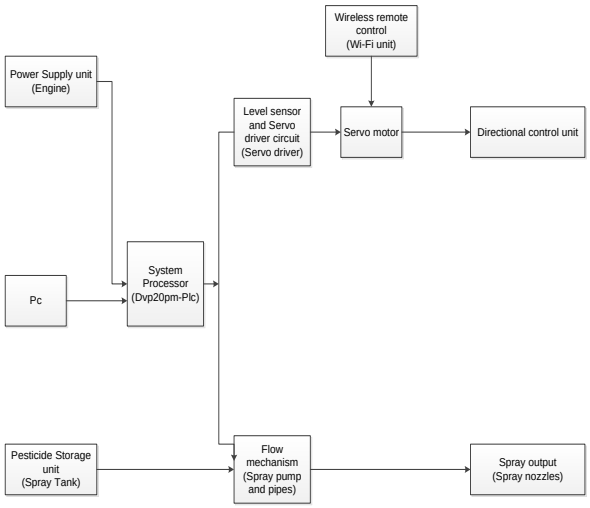

Figure. (1)Block diagram of the whole process

4.3 Input unit

(1)The Input unit consists of the power supply unit which provides power to each upper and lower control system of the electronic components inside the robot.

(2)The pesticide storage unit for storage of pesticide in a liquid form.

4.4 Spray and Control processing

(1)The DVP 20 pm Programmable Logic Controller is the main Brain of the Robot.

(2)The Driver software program on a PC is connected to the DVP 20 pm PLC which in turn is connected to the three servo motors and servo drivers to driving the robot in the required direction and speed.

(3)The Spray Pump is used to transfer the pesticide from spray tank to the sprayer nozzles through the pipe.

(4)The pesticide flow level control software program on a PC is connected to the DVP 20 pm PLC which in turn is connected to the spray pump and alarm sending device for the task of controlling the pesticide level and it's flow mechanism, then when the spray tank is finished pesticide the alarm sending device has been understood the situation and being capable to give noise signal to PLC and the PLC also give another signal to PC, so the operator input more pesticide inside the spray tank.

(5)The arms directional movement control software program on a PC is connected to the DVP 20 pm PLC which in turn is connected to the two linear actuators which are connected with the two arms each other, sprayer nozzles and pipes are needed for manipulating the motion and direction of the two arms in the specified path and direction.

(6)The two rear legs directional movement control software program on a PC is connected to the DVP 20 pm PLC which in turn is connected to the two linear actuators which are connected to the two rear legs each other, the two rear wheel are needed for the task of manipulating the motion and direction of the two rear legs according to the width of the rows.

4.4 Output unit

(1)The direction and path planning of the robot is controlled by Directional Control unit.

(2)The pesticide has been sprayed by the Spraying unit in specified direction and area.

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5. DESIGN AND SOFTWARE DEVELOPMENT FOR UPPER CONTROL SYSTEM.

Delphi environmental development tool helps to design a software programming; two elements must be taken into consideration: the first one is the structure of the program i.e. the flowchart, and the second is the language in which the program will be written. Delphi programming permits to develop the applications and software for windows. It is a tool that makes a visual conception for functions, to the programming object. Besides, it maintains the part of the source code. This language uses a friendly interface to the program. All the common parts of the windows graphical user interface, like forms, buttons and lists objects, are included in Delphi as components [5].

5.1 Design and Software development for Spray Tank Control

The designed software program has been used two buttons, button 1 is used to turn on the spray pump to fill chemical inside the spray tank depending on the value of upper limit and button 2 also is used to turn off spray pump, when it is reached the lower level depending on the value of lower limit. The program is written inside the form using the two buttons to make the spray pump on/off. The two levels and edits command are used for displaying the limit names and levels of pesticide which is stored inside the iTank command. The pesticide level inside the spray tank is fixed by the developed software program, including iOdometer command which has shown the pesticide level in the spray tank. Then the created software program on a PC is connected with PLC MSComm serial communication software.

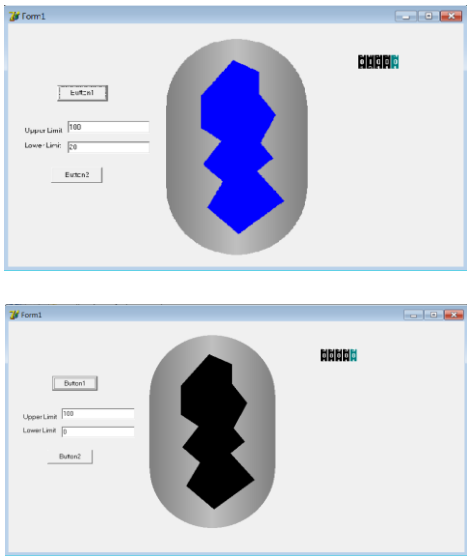

Figure.(2)Spray tank design on delphi7 (a)Spray tank is full of pesticide (b)Spray tank is empty of pesticide

The spray pumping system is helped to pump the pesticide liquid from the spray tank into the spraying place. It has consisted of spray tank, spray pump, relays with PLC in the spraying process.

Figure. (3)Spray tank of the Robot

5.2 Design and Software development for Path Planning

To a more principal and more detail navigation purpose of the spraying robot, Delphi7 programming language is used to design the software program that allows the robot to move in the specified path. As indicated in the above figure3, the path is found by figuring out the least number of lines which acts as a row, the robot can move to reach the target place. As soon as the path is found, the robot is moved from one row to the next. Depending on this software program and since the robot arm length is 6m, so the user can input any value on X and Y buttons to fix the row width and row distance to generate and figure out the number of lines rows by pressing generate button. The robot being followed each line of crop rows to go forward, turn left at 180 degrees, backward, turn right at 180 degrees to do the spraying process. The designed software input on PC, then it can communicate with PLC.

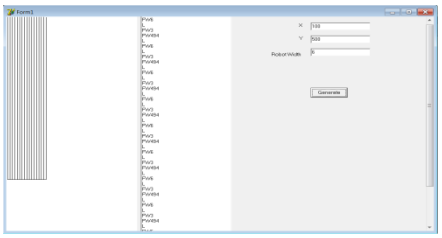

Figure. (4) Path planning design on delphi7

Since the robot is a three-wheel robot, so the two rear wheels are responsible for controlling the driving system, while the front wheel handles the steering system and direction of the robot. The driving system is used to control the movement and position of the robot until reaching the target place. It has been consisted of, in the front one wheel and at back two rear wheels with their servo motors and servo drivers, including extension module of Dvp-32HNOOT which are connected with PLC for receiving and sending data's depending on delphi7 software program in a PC to do the robot path planning.

Figure. (5) Path planning of the robot

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5.3 Design and Software development for Arms Control

The software program is designed by using delphi7 programming language to control the movement and direction of the two arms in the left, right, upward and downward directions at different angles for opening them with the sprayer nozzles before spraying chemicals, then after for returning to their original place to the same directions at different angles and closing them with sprayer nozzles after spraying chemicals. So the developed software program is used as an input interface with the PLC and when the outputs of the PLC activated using button 1, then signal transferred from PLC to the two linear actuators to open the two arms in required directions and button1 command made the iSwitched command to be switch on for opening them, after that each sprayer nozzles that are connected with the two arms can be sprayed chemical on the crops that have been attacked by diseases, after the completion of the spraying process, again PLC will be sent signal to the two linear actuators to close the two arms and return them to their original place.Button1 command was made the iSwitchled command to switch off for closing them, overlap each other and stopping the spraying process. The software program is capable of to control the opening and closing process, movement and direction of the two arms of the robot at various angles from 0-180 degrees.

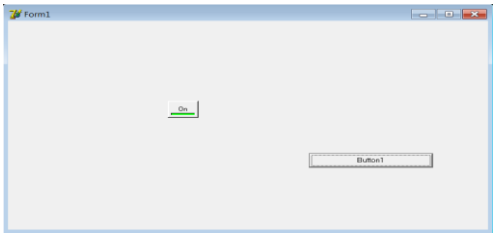

Figure. (6) Arms control design on delphi7

The spray robot has consisted of two linear actuators, sprayer nozzles, pipes and Delphi application code. The robot arms are designed and programmed to spray chemicals using their nozzles on the leaves of defected plants. The robot has two arms including many sprayer nozzles on it.

Figure. (7) Robot arms control

5.4 Design and Software development for Legs Control

The software program is designed for the delphi7 programming language to control the two legs being capable of resizing and repositioning themselves using button 4 manually and button 6 automatically according to the width of each row, such as button3.The two level commands are represented the rows names, the two edit commands are helped for inputting the value of rows to resize as well as reposition the width of button1 and button2 commands that are acted as rows in a field. Before the spraying process was started, the user has adjusted the width or gap between the two legs in the software program that is button 1 and button 2 value to resize them according to the width of the row. After the spraying process has been finished, then the user has repositioned them to their original place using button 5.

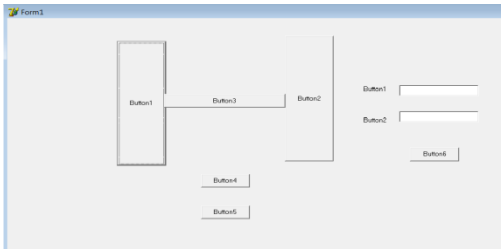

Figure. (8) Legs control design on delphi7

The spray robot is included two rear legs at the back part. It has consisted of two linear actuators, two wheels with its servo motors and servo drivers. The above software program is used to manipulate the movement of the two legs in the left and right directions of the spray robot. The program is proposed for resizing and repositioning of the two rear legs according to the width of rows.

Figure. (8) Robot legs with nozzles

6. DESIGN OF OTHER COMPONENTS AND TECHNOLOGIES

After the software program design and selection of required equipment's such as spray tank, arm with nozzles, path planning (wheels and motors) and legs(square pipes) with linear actuators are completed, then it is needed to select other components, such as servo motor, servo driver, engine which give power to the robot, PLC, CCD camera, PC, 3d controller, operator seat and other devices to meet the software program design as well as functionality requirements of the spray robot.

7. PC AND PLC COMMUNICATION

The main brain of the spray robot was DVP 20 pm type of PLC. Early programming logic controllers (PLC) are designed to replace relay logic systems. These PLC's are programmed in "Ladder Logic", which resembles a schematic diagram of relay logic. It has also the ability to arrangement the inputs or outputs. PLC represents such a universal controller. It can be used for different applications and via the program installed in its memory, provides the user with a simple means of changing, extending and optimizing control processes. The original plc's tasks are involving the interconnection of input signals according to a specified program and if "true" switch the corresponding output. [6]

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The design on automatic spray painting robot system based on PC-PLC network control is featured by low production costs and good system openness.[7]In this project the PC and PLC communications are based on MSComm (Microsoft control) which provides serial communication function between PC and PLC.MSComm is used binary data attribute to send again receive data through serial port. It is also important input and output data attribute. The input data attribute is used for reading the in receive buffer data while the output data attribute is used for writing the send buffer data. PC and PLC are used RS485 interface.

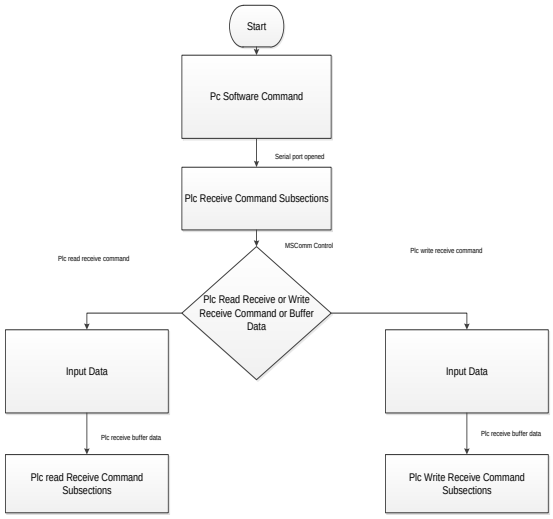

Figure. (9a) Flow chart of Plc Command Receive Subscriptions from PC

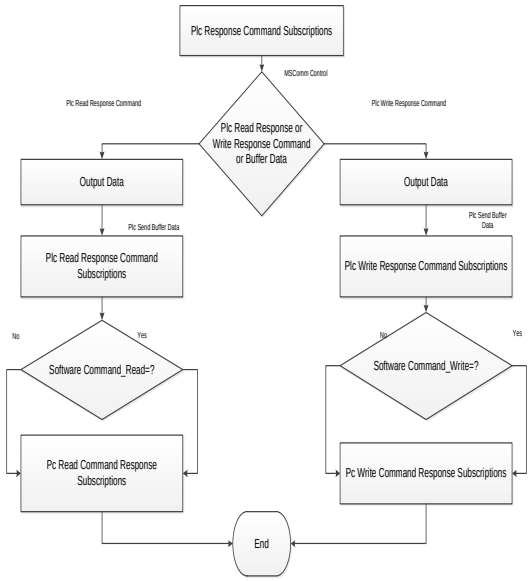

Figure. (9b) Flow chart of Plc Command Response Subscriptions to Plc

7.1 PC and PLC Communication based on Spray Tank Control

The developed software program in a Delphi language is installed in a PC and it will be communicated with PLC during the execution of spray tank. The PC is sent a signal to PLC to turn on/off the spray pump, PC program being powered to control the pesticide and spray tank flow level also rate. When the spray tank has been finished pesticide inside, immediately the PC is sent a signal to PLC, PLC to alarm sending device, finally because of the alarm noise, the operator has understood it and input more pesticide inside the spray tank.

7.2 PC and PLC Communication based on Path Planning

To meet the user's need for DVP-PLC programming examples, it needs to provide examples of basic instructions including sequential/position control, time counting and input/output control in DVP-PLC application examples[8].The created software program is inputted in a PC that supports the user for ordering the robot to move in the required path. Again it will be communicated with PLC, thus PLC can be manipulated the spray robot motors. Based on the PC and PLC communication, the first step is, the robot driving motors are started working and the robot driving wheels are started to move forward in a straight line depending on the width and distance of the rows to perfume spraying process between rows, the second step is, the steering motor of the robot made the steering wheel to be turned to the right direction with an angle of 180 degrees to continue to the next row, at this position it is not done the spraying process. Then after again the driving motors with their wheels are made the robot to move backward in a straight line and begun spraying process. The spray robot has repeated the process until it will be reached the target position and also in the left direction. The PC has been controlled the direction, position and PLC the time, motors of the robot.

7.3 PC and PLC Communication based on Arms Control

After installing the Delphi program on a PC, then the operator being activated the program, so the PLC can be received signal from PC, then PLC is powered on the two linear actuators to control the two arms motion in the left, right, up and down directions at various angles from 0-180 degree to make the spraying process easy. When the operator is inactivated the program, the PLC is powered off the two linear actuators.

7.4 PC and PLC Communication based on Rear Legs Control

The developed software program on Delphi programming language is installed on PC and PC will be communicated with PLC. Thus when the software program is activated, the PC is sent a signal to PLC, then after the PLC is powered on the two linear actuators to manipulate the movement and direction of the two rear legs in the left and right directions for resizing and repositioning them. The two linear actuators are connected with the two rear legs. When the program is inactivated, the PLC is powered off the two linear actuators.

8. TESTS

The following shows the tests done to check the functionality of the upper control system software programs with PLC. This is done to make sure that the robot each upper control system parts with their developed software programs on Delphi7 and the lower control system that is PLC are worked together to complete the control system of the robot for the task of spraying pesticide on the crops.

Tests are made on spray tank, arms, rear legs and path planning. The designed software programs have been controlled the spray tank level, arms movement and direction, rear legs movement and direction as well as robot motion in the required path respectively, at a time by communicating with PLC.

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Figure. (10) Spraying Robot in Agricultural Field

During the experimental test of the robot in the field, it was taken only 55 minutes for a distance of 28meter.Before the robot movement is started, the spray nozzles head have been opened manually, then the robot will be begun the spray job. The robot is capable of driving to the end row and back along the pesticide spraying manually or automatically. It can be worked in various weather conditions, such as mud, humidity, wet and so on. The robot is showed constant velocity for various speed and time as indicated in the diagram below.

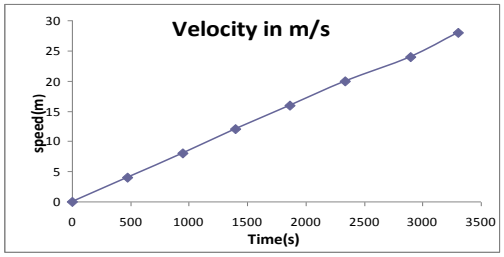

Figure. (11) Velocity in Distance

The spray pump force with the spray tank was indicated enough working efficiency and less time consume. The robot arms with spray nozzles are moved to the left, right, up, down directions and the legs also to the left, right directions according to the appropriate crop height and rows width.

Measuring the distance of farthest spraying 28m., the spray angle can be controlled at 0-180 degree, an angle of the spray areas of 0.008484m/s.The spray tank was full of pesticide(10L), the spray tank after spraying took 0.59minutes 0.00seconds, showing that much spray liter per minute.

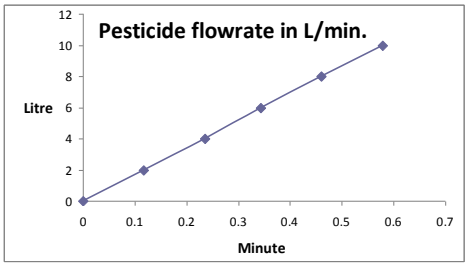

Figure. (12) Pesticide Flow Rate in the Spray Tank

9. CONCLUSION

The proposed approach can deal a wide number of environments. The software control system approach has an advantage of adaptively such that the design and software development for the upper control system of spraying robot approach works perfectly even if an environment is various.

The proposed approach has made the robot able to achieve these tasks:

1. Control the spray tank level and pesticide flow rate with an applied pressure of 40 psi with spray pump open flow 4.5 GPM (17.0 LPM).For 10L of spray tank, the spraying process has taken 55 minutes for a distance of 28m/s.
2. Control the robot movement in the required and planned path and direction in rows of field. The robot was able to navigate itself as well as with operator in the upward, downward, forward and backward direction in each row for spraying chemical. Its performance was well enough and taken 55 minutes for a distance of 28m/s.
3. Control the robot arms motion in the direction of left, right, up and down. They are capable of moving at an angle of 0-180 degree in each direction. The opening and closing system of the arms was taken 45 seconds.
4. Control the robot rear legs motion in the direction of left and right. Each of them is capable of resizing and repositioning according to the specified direction to cover a vast area for spraying pesticide. The resize and reposition process of the rear legs have been taken various times neither in minutes nor in seconds depending on the width of each row.
5. Recently, some software programmers are designed on Delphi7 programming languages that help the user to manipulate each upper control parts alone, but in this project the developed software's are able for manipulating each upper control system parts once at a time for spraying task, so it can be taken as a new innovation in the robotic technology.
6. Hence; the results are promising for future work of this domain and in accompaniment; it will be also helpful for using for different applications and works.

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