Autonomous Navigation of non-holonomic Vehicles Using Interval Type-2 Fuzzy Logic System and Neural Network in Simulated Environment.

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Abstract-**Orientation is required in the navigation applications in the outdoorslike horticulture, forestry, agriculture, civil or social works, industrial works, geo-studies, space works and other applications of unloading or loading of vehicles.The main aim of the research is to develop algorithm for autonomous navigation of non-holonomic vehicles using interval type-2 fuzzy logic system and neural networks in simulated environment using MATLAB. It was noticed that network configuration and training of neural network indicates that good training results could be achieved. From the findings of the analysis, it was observed that by adopting the fuzzy control improved by neural network, it can able to identify the nearest way of vehicle efficiently.For future work it can be extended for autonomous navigation of non-holonomic vehicles using artificial intelligence techniques in simulated environment using LABVIEW platform which can be applied to environmental applications.**

Keywords: non-holonomic vehicles, interval type-2 fuzzy logic system, simulated environment, neural network, autonomous navigation, Foot print of uncertainty (FOU).

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I.   Introduction

According to Ibrahim et al (2004) and Paromtchik (2004) autonomous navigation is a needed motion of mobile robot without intervention of human for achieving a target position with the needed orientation. It is a benchmark area for research since its applications could be applied in wide areas like civil or social, industrial automation, precision space or agriculture and exploration works. Moreover, vehicle type in robots, its kinematics and physical parameters are decided based on the needs of the area of application. Perez et al (2003) and Rudzinska et al (2005) pointed out that unique constraints on their navigation together with maximum speed and size (physical constraints) are referred as the kinematics constraints of robot. At the same time, it was stated that mobile robots are classified based on the motion type namely non-holonomic and holonomic (Perez et al, 2003).

It was mentioned by Adouane et al (2011) and Adouane (2009) that holonomic robots are some of the research and commercial robots. These vehicles have rotation motion and decoupled translation. They are capable indifferentiating each and every component of their orientation and position independently. Kim et al (2003) stated that the non-holonomic robots cannot be able to modify their orientation without modifying the position or/and could be able to navigate in restricted number of directions based on their orientation and shape of legs or wheels. Non-holonomic robots are urged for translating their move for changing to end orientation (Hoang and Nguyen, 2007 and Kim et al, 2003).

Wheeled mobile robots are adopted by industrial manufactures at several places. Requirement for controlling the formation of multi-robot systems to perform a coordinated task have resulted in the emergence of complicated research field. Issue of formation control is referred as identifying a control algorithm to assure that various autonomous vehicles could uphold a particular formulation or particular formations set when traversing a path (Hoang and Nguyen, 2007).

II.   Problem Identified

Non-holonomic vehicle have some constraints related to kinematics owing to its physical constraints such as maximum steering angle, speed, size and so on and geometrical features. Navigation of non-holonomic vehicle needs a high expertise degree and mostly complicated manoeuvring for reaching at close actual place with an end orientation during its starting place then the orientation is changed. Thus, it is significant to carry out researches on navigational strategies to transform non-holonomic vehicles into autonomous vehicle navigation (Perez and Alegre, 2001). Therefore this study intends to concentrate on autonomous navigation of non-holonomic vehicles using interval type-2 fuzzy logic system and neural network in simulated environment.

III.   Aim

Aim of the research is to investigate in detail about autonomous navigation of non-holonomic vehicles using interval type-2 fuzzy logic system and neural network in simulated environment.

IV.   Objectives Of The Research

i.   To develop an algorithm for autonomous navigation of non-holonomic vehicles.
ii.   To develop algorithm using interval type-2 fuzzy logic system and neural network with specific reference to simulated environment.
iii.   To provide valuableimplications for agricultural application using interval type-2 fuzzy logic system and neural network.

V.   Literature Review

According to the research by Mutneja (2008) explains the deployment of a navigation strategy for robotic vehicle which is non-holonomic to a parking space in the simulation environment using interval type-2 fuzzy sets for designing a fuzzy control system for automatic navigation. In MATLAB, graphical user interface was designed for aiding the navigation simulation to a designated parking location, initiating from any random place in a designated area. Parameters for simulation encompasses algorithm for trajectory traversing, fuzzy t-norm method, initial position, and boundary of vehicle, customized trace display of rear and front wheels and so on. Only initial and finishing points are given and robot itself carries out the trajectory. In this research, two algorithms for trajectory traversing such as LPA (linear path approximation) and CCA (continuous curves approximation) for motions of non-holonomic were combined in GUI system design. It was found that system of autonomous navigation on the basis of interval type-2 FL or fuzzy sets enhances, as the FOU maximizes up to a certain limit, beyond which aliasing kind of values in the variable seems to invoke the non-desirable rules to fire. The interval type-2 FL system response becomes similar to that of FL system in the type-1 as the expansion of uncertainty is minimized by minimizing the FOU to zero. Thus it can be inferred that system of autonomous navigation on the basis of interval type-2 FL or fuzzy sets enhances as the FOU maximizes up to a certain limit, beyond which aliasing kind of values in the variable seems to invoke the non-desirable rules to fire.

Vivekananthan and Karunamoorthy(2011) discussed about the modelling and controlling strategy of the movement of three wheeled non-holonomic mobile robot. Controller of fuzzy logic was designed on MATLAB to address the issue of tracking control for specified orientation and position. In this research, trajectory was adopted to obtain the robot's kinematic relations at the acceleration levels, velocity and displacement. At the same time, it was noted that deployment of such control strategy for robot is a simple approach of geometry and simulations provide satisfactory outcomes. In addition to this, it was noted that suitable inputs of velocity control was acquired from algorithm of FL which stabilizes the control of kinematic closed loop. Thus it can be concluded from the literature that deployment of controlling strategy for robot is a simple approach of geometry and simulations that provide satisfactory outcomes.

Martinez et al (2009) developed a controller of trajectory tracking by considering the dynamics and kinetics of autonomous mobile robot with the help of genetic algorithms and type-2 FL. Genetic algorithms are adopted to optimize the trajectory tracking constants and to optimize the membership function's parameters for FL control. Sidhu et al (2012) discussed about the implementation of strategy for non-holonomic vehicles navigation using IT2 (Interval type-2) system of fuzzy logic with specific reference to simulation environment. This research discusses certain strategic aspects for example t-norm operator's choice and FOU (footprint of uncertainty) amount in orientation of vehicle in simulation environment for non-holonomic vehicle's autonomous control that otherwise needs manoeuvring and expertise in high degree. In addition to these, it was noticed that adoption of MIN as operator of t-norm maximizes the vehicle accuracy to reach at designated location of parking. Thus it can be inferred from the analysis that FOU amount in orientation of vehicle in simulation environment for non-holonomic vehicle's autonomous control otherwise needs manoeuvring and expertise in high degree.

Meshram (2014) developed a formation and strategy for motion control for a wheeled mobile robot (WMR) group. Developing effective mathematical model is totally complicated because of inherent non-linearities and other obstacles included in acquiring reliable measurements. Purpose of this research is to propose WMR, placed them in a framework of leader follower and controller of motion on the basis of fuzzy logic (FL). FL provides humans like reasoning behaviour or thinking to a machine. Apart from these, it was noted that FL controllers have the potential of adopting information which has been retrieved from the experienced operator of human beings more efficiently than traditional controllers. Controller of motion is designed using interval type-2 FL. This would give the robots the probability to shift from starting position to final position. Thus it can be concluded that the FL controllers have the potential of adopting information which has been retrieved from experienced operator of human being more efficiently than traditional controllers.

Chen et al (2014) focuses on the method of motion planning on the basis of RBF (Radial basis function) neural network for guiding the autonomous vehicle with respect to an unstructured environment. Developed algorithm obtains the drivable region from the grid map perception on the basis of global path that is present in the road network. Algorithm of motion planning parameters is checked through the experiment and simulation. It was noticed that the developed approach gives a smooth, safe and flexible path

that could fit any road shape. Apart from these, it was found that the developed methods are highly efficient in planning the path of vehicle and provides better quality in the motion. Thus it can be understood from the analysis that the developed approach gives a smooth, safe and flexible path that could fit any road shape.

VI. Research Design

Purpose of the research is to develop algorithm for autonomous navigation of non-holonomic vehicles using interval type-2 fuzzy logic system and neural network in simulated environment. FL involves fuzzy systems (FS) are represented as approximate reasoning and non-statistical uncertainty and fuzzy operations adopted for making inferences.

A. Interval Type-2 Fuzzy Sets

Fuzzy logic composed of fuzzy systems. It is the way of expressing approximate reasoning and non-statistical uncertainty and operations of fuzzy adopted for making inferences. Unlike conventional Aristotelian two-valued logic, in system of fuzzy logic, variable belongs to the set which happens by a degree over the range such as [0,1]. According to Karnik and Mendel (2001) computational complexities maximize with number of type-2 FSs in FL system. Complexity's burden minimizes most of the folds with specific case of type-2 FSs namely interval type-2 fuzzy systems, where all secondary membership functions of every type-2 fuzzy system becomes interval sets that is ($\mu_{\tilde{N}}$ (s,r) = 1) rather than type-1 FSs.

$$\tilde{N} = \int_{s\varepsilon S} \int_{r\varepsilon B_s} \mu_{\tilde{N}}(s,r)/(s,r), \ B_s \subseteq [0,1] \qquad (1)$$

Mathematically, from 1, this equation is derived

$$\tilde{N} = \int_{s\varepsilon S} \int_{r\varepsilon B_s} 1/(s,r), \ B_s \subseteq [0,1] \qquad (2)$$

$$\mu_{\tilde{N}}(s= s', r) = \mu_{\tilde{N}}(s') =$$

$$\int_{r\varepsilon B_s} d_{s'}(r)/(r); \ B_{s'} \subseteq [0,1] \qquad (3)$$

And (3) minimizes to

$$\mu_{\tilde{N}}(s= s', r) = \mu_{\tilde{N}}(s') = \int_{r\varepsilon B_s} 1/(r); \ B_{s'} \subseteq [0,1] \qquad (4)$$

B. Representation of FOU

There are numerous ways to represent FOU (Liang and Mendel, 2000, Liu et al, 2006 and Mendel, 2007) and such approaches describe interval type-2 fuzzy systems. FOU of an interval type-2 FS, say Ñ, could be represented using only upper and lower bounds of uncertainty included and they are referred as L and U and are as denoted as $\mu_{\_\tilde{N}}$ (s) and $\mu^{-}_{\tilde{N}}$ (s) respectively, for $s\varepsilon$ S

$$\mu_{\_\tilde{N}}(s) = F_{\_}(\tilde{N}); s\varepsilon \ S \qquad (5)$$

$$\mu^{-}_{\tilde{N}}(s) = F^{-}(\tilde{N}); \ s\varepsilon \ S \qquad (6)$$

$F_{\_}(\tilde{N}) = U_{s\varepsilon S}B_{\_s}$ and $F^{-}(\tilde{N}) = U_{s\varepsilon S}B^{-}s$ where $B_{\_s}$ and $B^{-}s$ denote the lower bounds and upper bounds on B_s, respectively.

Moreover, $\mu_{\_\tilde{N}}(s) = \mu^{-}_{\tilde{N}}(s)$ that is all secondary uncertainties does not appear, interval type-2 fuzzy system minimizes to type-1 fuzzy system. Stated mathematically as:

$$\mu_{\tilde{N}}(s) \mid_{\mu_{\_\tilde{N}}(s) = \mu_{\_}\tilde{N}(s)} = \mu_N(s) \qquad (7)$$

Interval type-2 FL system was well standardized in Mendel (2007) for different de-fuzzification, operators and methods of type reduction and more.

C. Neural Network

Neural network (NN) is a parallel network which has interlinked elements in the analog processing that is neurons. Parallel nature of NN allows it to reach speed of computation which is not possible by traditional sequential computers. Individual element in the processing function is very simple and mostly considered as the weighted input's sum, passed through functions of non-linear and considered as sigmoid-shaped. Neuron's weights are the parameters, which define the network functionality. NN is made up from one or more hidden layer (HL), an output layer (OL) and an input layer (IL). Each node of IL is linked to a node from HL and every node from HL is linked to a node in OL. Moreover, there is some weight link with each and every connection. IL shows the raw data which is fed within the network. Such network part never modifies its values. At the same time, it was stated that every single input given to the network is duplicated and transmits down to nodes in HL. Such layer accepts information from IL. It adopts values from the input and changes them using certain value from weight, such value is thentransmitted to OL but it would be changed by certain weight from link between output and hidden layers. Process information in OL received from HL gives an output. Such output is processed by function of activation (Cilimkovic, n,d).

VII. Limitations Of The Research

i. Findings of the study are restricted to non-holonomic vehicles.

ii. This research focuses on the interval type-2 fuzzy logic system and neural network with respect to simulated environment.

iii. This research exclusively considers about autonomous navigation of non-holonomic vehicles using interval type-2 fuzzy logic system and neural network in simulated environment.

iv. This study is limited to agriculture applications alone.

VIII.   Results
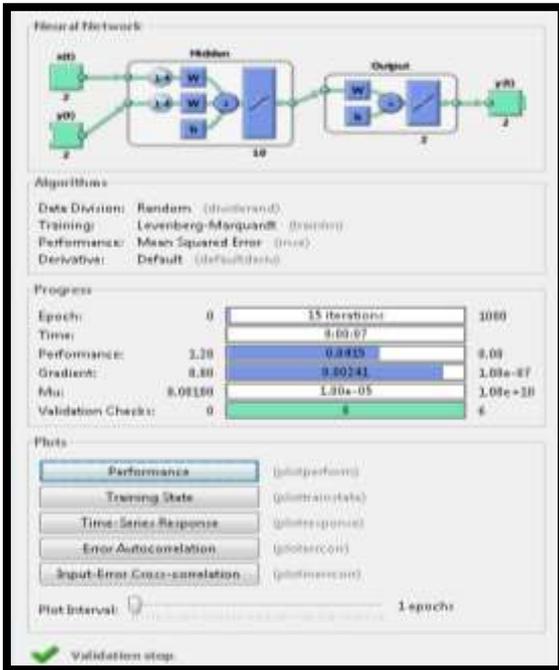
Figure 1

Figure 1 indicates the network configuration and training of neural network. This indicates that good training results can be achieved.
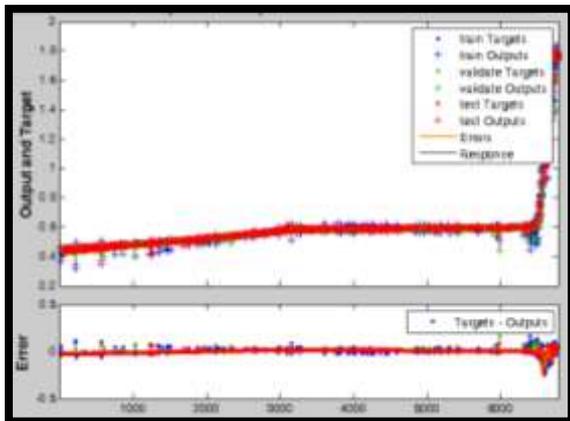
Figure 2

Figure 2 explains the output and target value and error value. Blue colour * indicates train targets. Blue colour + shows train outputs. Green colour * shows validate targets. Green colour + shows validate outputs. Red colour * indicates test targets. Red colour + shows test outputs.Orange colour line indicates the errors in the output and target. Violet colour – indicates response.
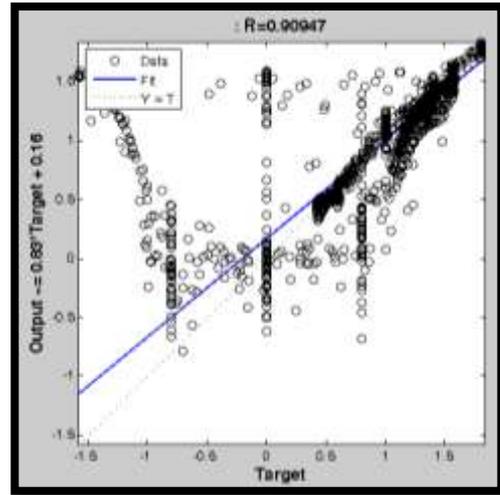
Figure 3

Figure 3 explains about the regression value in the neural network. X axis represents target value. Y axis represents output value. When output value is 0.83, target is +0.16 then regression value is equal to 0.90947.
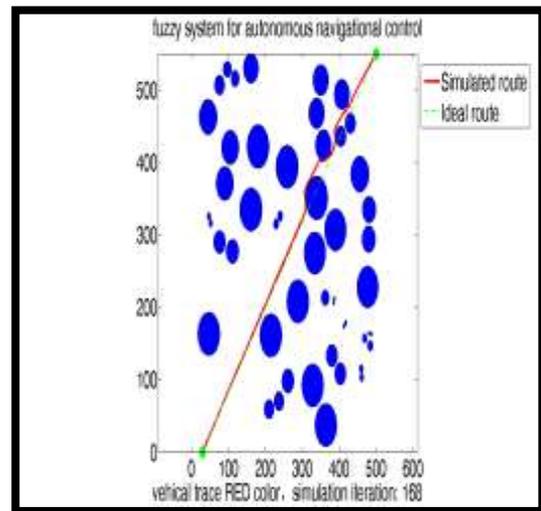
Figure 4

Figure 4 explains fuzzy controlled neural network for autonomous navigational control. It indicates the vehicle route identified during its target way. By adopting the fuzzy control improved by neural network, it can be able to identify the nearest way of vehicle efficiently. Green line denotes ideal route from initial point to target. At the same time, it does not exist as there are hurdles on its way. Red line denotes the simulated route navigated by neural network and fuzzy control. For simulating the vehicle navigation, blue circle are the obstacles which is created randomly between vehicle's initial to the target point for simulating the random and complicate real environment. Further, vehicle begins from its initial point and far away to the target point with angle of direction calculates from coordinates. At the same time, once the vehicle tracks a hurdle on its way in single step, then it will select to modify

the angle of direction which is decided by integrated neural network and fuzzy control methods and finally loop ends once the vehicle reaches at its target.

IX. Implications

The main contribution of the research is to focus on autonomous navigation of non-holonomic vehicles using neural network and interval type-2 fuzzy logic system in simulated environment can be applied to the agricultural applications like fielding, horticulture. Non-holonomic navigations could be successfully adopted in the agriculture area. It needs intelligent and fine control strategy. Developed algorithm could be successfully applied to the agricultural applications.

X. Conclusion and Future Work

Purpose of the research is to develop algorithm for autonomous navigation of non-holonomic vehicles using interval type-2 fuzzy logic system and neural network in simulated environment using MATLAB. From the analysis, it was found that network configuration and training of neural network indicates that good training results could be achieved. It was noticed that once the vehicle tracks a hurdle on its way in single step, then it will select to modify the angle of direction which is decided by integrated neural network and fuzzy control methods and finally loop ends once the vehicle reaches at its target. From the findings of the analysis, it was observed that by adopting the fuzzy control improved by neural network, it couldbe able to identify the nearest way of vehicle efficiently.It was clear from the analysis that when integrating neural network and interval type-2 Fuzzy logic could be able to perform autonomous navigation of non-holonomic vehicles. For future, work can be extended for autonomous navigation of non-holonomic vehicles using other artificial intelligence techniques in simulated environment using LABVIEW platform which can be applied to environmental applications.

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