Human-Learning Steering Control Based-on Artificial Neural Network and Visual Servo

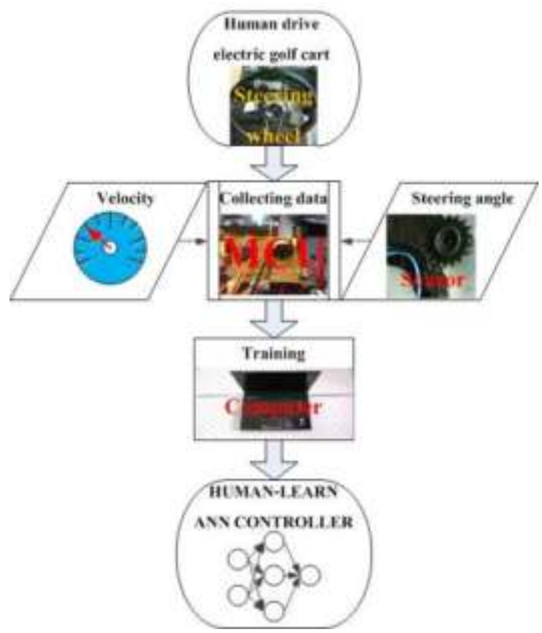
Arthit Srikaew[1], Prayoth Kumsawat[2], Kitti Attakitmongcol[1] and Bannakit Khitthuk[1]

***Abstract*—**This article presented the design and built the prototype system of steering control for real use in vehicles in order to figure out the suitable value for steering control with steering devices and automatic function by using human steering control data as a prototype. The mentioned data are obtained by determining men to drive vehicles using genuine steering wheels and had the system learned, remembered the behavior patterns of steering control from artificial neural network (ANN) technique. And it could sort out their groups with the abrupt awareness, the remembrance of behavior patterns of new steering control which the system had not either learned or remembered before by using adaptive resonance theory technique (ART). The essential information in training included front wheel angle values, vehicle velocity, and concurrent illustration data for automatic steering control. The results of research were the acquisition of steering control prototype which was suitable for turning in accordance with situations resembling human steering control with genuine steering wheel, and the proficiency in selecting behavior patterns of steering control.

***Keywords*—**Artificial Neural Network, Adaptive Control, Human-Learning.

I. Introduction

FOR working on authentic routes, the vehicle steering control with the steering device is rather difficult to control vehicles turning to suitable directions. Likewise, the determination to acquire suitable turn angle for vehicles in various situations is not easy for the automatic steering control. Despite the availability of controlling PI device of steering control helping such system achieve the referred goals which stem from steering devices, PI device cannot determine appropriate turn angle value for steering control system. Thus, this research used human steering control to determine suitable turn angle and had artificial neural network learned, and remembered the function of steering control. Many researches have presented steering control system by using artificial neural network (ANN). For example, the use of back-propagation algorithm in automatic steering control system with ANN instead of following flow chart, [1] the search for the model of steering control with Neural-fuzzy technique, [2] the steering control system with artificial neural network (ANN) of modular by coaching the system with the calculation for the lateral position of vehicles in advance, [3] the steering control system of PID-Fuzzy-Neural network (PID-Fuzzy-NN) [4] the search for steering control model with artificial neural network radial basis function for automatic steering control system [5]. The human-learning steering control by using artificial neural network emphasizing the adaptive control for steering control with steering control devices and automatic steering control is to imitate the similar or close to human steering control behavior with steering wheels. In addition, it can be practically used in real circumstances by determining vehicles used on authentic roads. Hardware which was used in this research included an electric golf cart, Electric Power Steering, EPS with a driving motor set, a notebook computer, a micro- controller, and a module converting signals from digital to analog.



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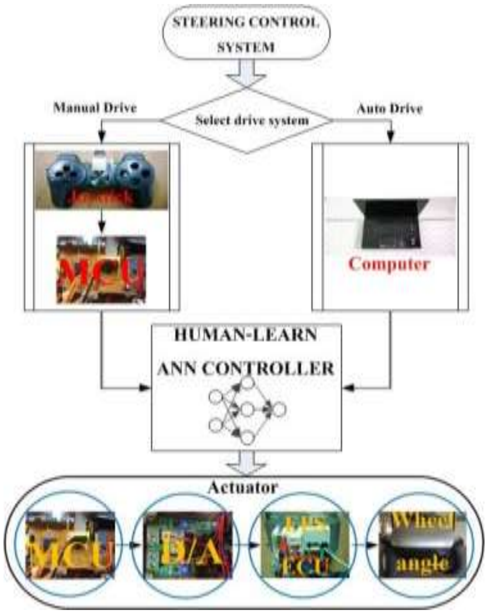

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Fig. 1: (a) Overview diagram of system training, (b) Overview diagram of actual

II. Human-Learning Steering Control Using Artificial Neural Network

Artificial neural network (ANN) is efficient and intelligent science which is popularly applied due to outstanding properties including learning and remembrance.

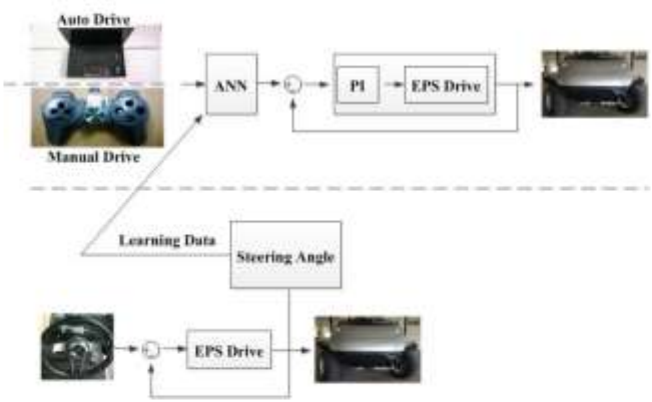


Fig. 2: Diagram of Learning and Actual operation of human-learning steering control with artificial neural network

This research comprised steering control both with automatic function and with steering devices. Both of them used multi-feed forward network architectural structure which was coached by using back-propagation algorithm in learning. The diagram of learning is shown in Figure 2. When considering N layers of network, output of that layer will be input of next layer.

The learning process of using steering control was to determine human to drive vehicles using steering wheel and using control devices on authentic routes according to stipulation including stable vehicle velocity while coaching, the required bends and the junctions to be trained. The data of two turn angle types were collected at those bends and junctions according to the stipulation. Then the data of turn angles were taken to send to ANN system for learning and remembering by choosing required patterns of steering control behaviors with steering wheel as prototypes, while the automatic operation particularly used some parts of steering control behavior with steering wheel and let the network establish potential steering control for directions and velocity.

The actual work operation of using steering device was when the controller controlled steering with steering devices, the value of referred angles would be sent to ANN which has already learned. The ANN would functionally adjust and reimburse that turn angle value to that of previously learned. The work operation is shown in Figure 3. In terms of automatic work operation, it was to choose required steering control behavior patterns and the network would functionally send learned turn angle value and concurrently control steering by itself.

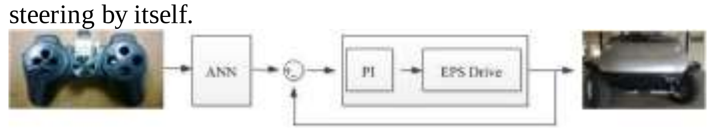


Fig. 3: The operation of human-learning steering control by using artificial neural network (ANN) with steering devices.

A. Segregation of Steering Control Behavior Patterns

For training steering control network with new information, it was crucial to divide the groups of steering control for the perception that the new information had not identical patterns as existing behavior patterns. As individual manual steering control was different owing to his or her aptitude and habit, the identification of behavior patterns and the segregation of steering control behavior were grouped by using adaptive resonance theory: (ART). ART is artificial neural network which possesses a competitive learning type with outstanding property of data segregation. Another exceptional property of ART is plastic status or the ability of response to new data when sending new data group to ART network which has not learned, remembered and grouped at all. ART network is able to learn new data group and additionally identify those data group immediately. The perception of ART network or the adjustment of weight can be operated according to the relation of equation as follows: Equation of Weight Adjustment

$$nw = (l_r * i_p) + ((1 - l_r) * w) \qquad (1)$$

Where nw = new Weight value, w = original Weight value, i_p = Input value , l_r = Constant learning

Hypothesis during steering control was when swiftly turning steering wheel with the turn max of turn angle data set having less value than the turn max of front wheels which were in the data set of the start turn with the slower turning, the algorithm was established by using Matlab program, extracting the time of turn start and the most value of turn angle of each turning data set in order to identify steering control behavior patterns.

The scrupulousness of group segregation was determined by vigilance which was in 0-1 range. If the vigilance value is small, the scrupulousness of group segregation will be small. This acquires small data sets but wide range of data. On the other hand, if the vigilance value is high, the scrupulousness of group segregation is high. This provides more groups of data sets but narrower range of data sets.

III. Human-Learning Steering Control Using Artificial Neural Network and Visual Servo

Steering control using visual servo which was corporately used with ANN in this research was to carry the data obtained from the illustration processing to find out the steering models while the CCD camera which was installed in front of the vehicles without any steering controller [5] to use as the value determining referred turn angle for control system and its input value by determining learning system and remembrance of human to be able to automatically control steering no-driver vehicles correctly and safely in accordance with human-learning steering control. Learning diagram and actual operation shown in Figure 4.

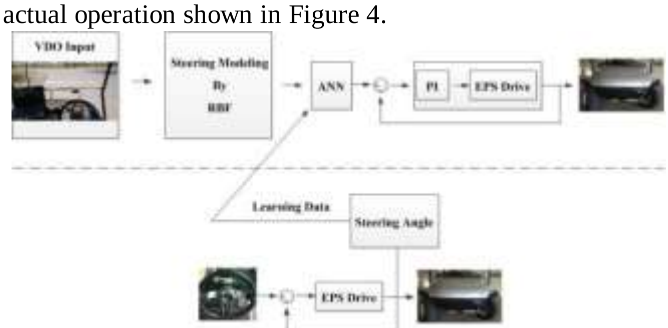
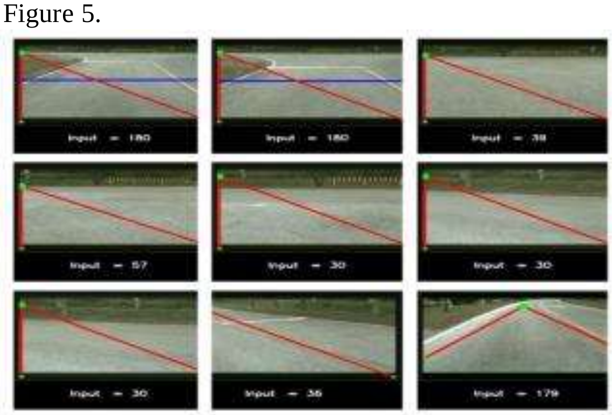


Fig. 4: Diagram of learning diagram and actual operation of Human-learning steering control with artificial neural and visual servo system

This research has taken directing point of movement values and turn angle values from the model of Radius basis function (RBF) to be used as Input for coaching Human-learning steering control network system with Artificial neural network system and Visual servo and referred target value for coaching network obtained by determining human to be steering controller with steering control at turn junction. The results showed the search for directing point of movement values and turn angle values from the model of RBF as shown in Figure 5.



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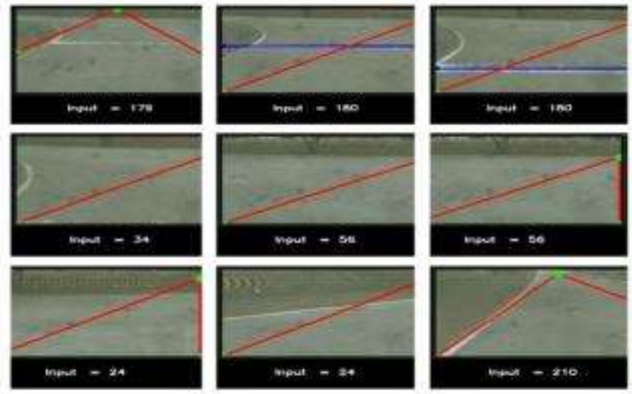

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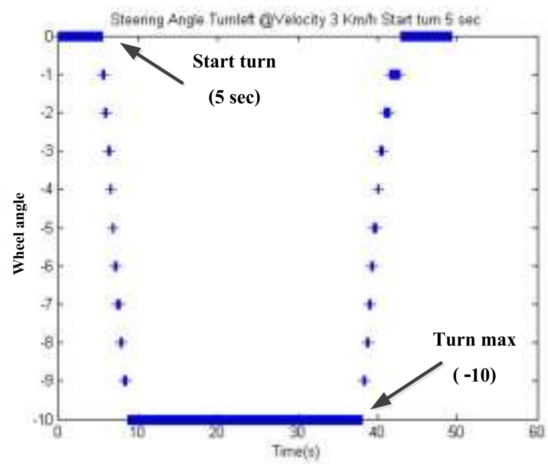
Fig. 5: Example of directing point of movement values from illustration data: (a) For turnleft, (b) For turnright.

IV. Results of Experiment and Analysis

A. Segregation of steering control behavior patterns

The segregation of steering control behavior patterns from coaching ART network was tested by using two example data sets of steering angle turnleft at velocity 3 Km/h as shown in Figure 6 (a),(b). The network was tested by using the two new additional example data sets in Figure 6 (c), (d).



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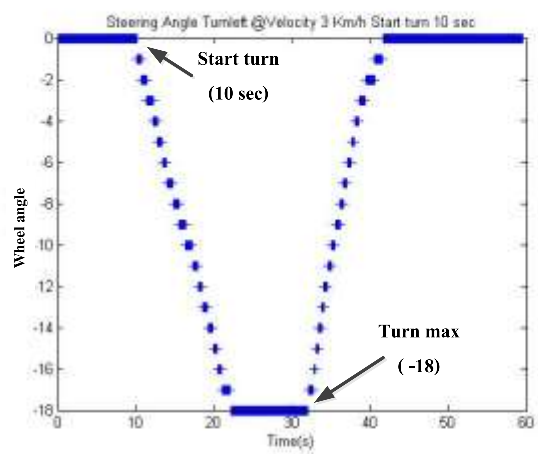

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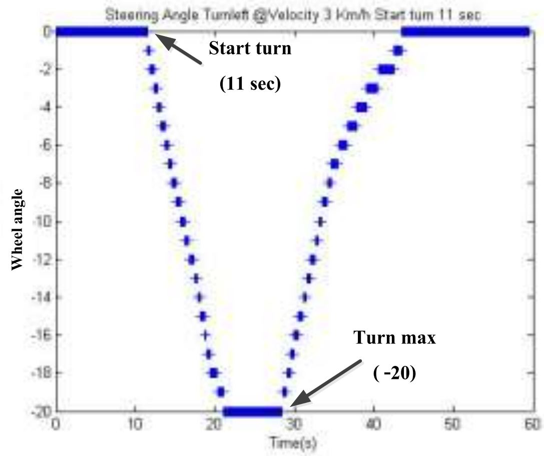

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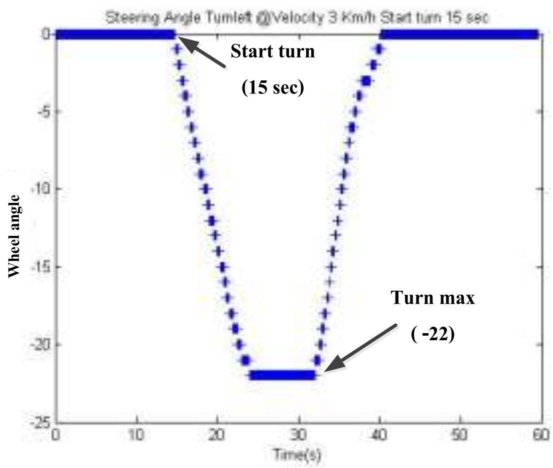


(d)

Fig. 6: (a) The 1st coaching data set started turning a steering wheel at the fifth second, (b) The 2nd coaching data set started turning a steering wheel at the tenth second, (c) The 3rd testing data set started turning a steering wheel at the eleventh second, (d) The 4th testing data set started turning a steering wheel at the fifteenth second

According to the results of steering control behavior pattern segregation with steering control from coaching Adaptive resonance theory with two coaching data sets, the network was unable to segregate data sets to be two groups with Vigilance 0.75. Similarly, the network testing the two data sets acquired the same results. In other words, both data sets were put in the first group since Vigilance value in this case was too small. Weight value from network learning was acquired from the relation and presented in Table I (Data test 1).

TABLE I
WEIGHT VALUE DATA SETS

Data test 1	Data test 2		Data test 3		
Weight at vigilance 0.75	Weight at vigilance 0.96		Weight at vigilance 0.96		
0.0500	0.0500	0.1000	0.0500	0.1000	0.1500
0.9000	0.9500	0.9000	0.9500	0.9000	0.8500
0.3200	0.4000	0.3200	0.4000	0.3200	0.2800
0.6000	0.6000	0.6800	0.6000	0.6800	0.7200

At vigilance 0.96, network was able to divide data sets into two groups because the value of vigilance in this study was sufficient to separate steering control behavior patterns with the example coaching data sets. The value of weight from learning network showed weight value from learning network as Table I (Data test 2).

According to the results of steering control behavior pattern segregation with steering control network with Adaptive resonance theory by using new data which network had never learned before. The network could identify as follows;

The 3rd data set started turning steering wheel at the eleventh second. This group was segregated as the 2nd group which was the same group of the second data set.

The2nd group which was the same group as the 2nd data set started turning steering wheel at 10th second. As steering control behavior pattern was close enough, the weight value was still as it was, and the tested data had been already set in the coached group, the new learning did not emerge as shown in Table I (Data test 2).

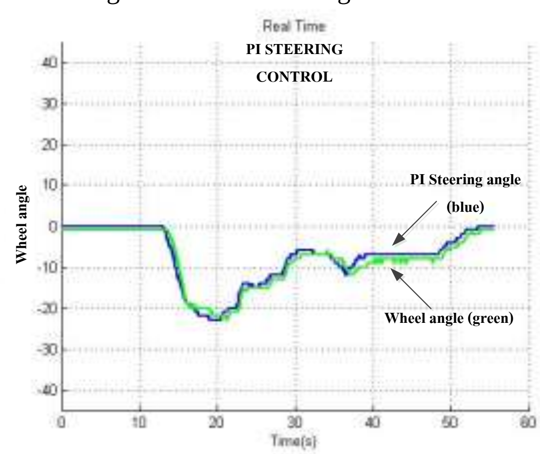
The 4rd data set started turning a steering wheel at the fifteenth second. This group was segregated as the 3rd group which was newly established because the steering control behavior pattern segregation was not sufficiently close to the coached group. This acquired learning (weight adjusting) and concurrently built new data group and weight value from learning new information of network as shown in Table I (Data test 3).

TABLE II
THE TABLE CONCLUDING THE RESULTS OF STEERING CONTROL BEHAVIOR SEGREGATION USING ART

(vigilance)	behaviors in steering control			
	the sample training data set		the sample testing data set	
	The data set no.1	The data set no.2	The data set no.3	The data set no.4
0.75	1	1	1	1
0.96	1	2	2	3

B. Human-Learning Steering Control by Using Artificial Neural Network

- Steering control with steering devices



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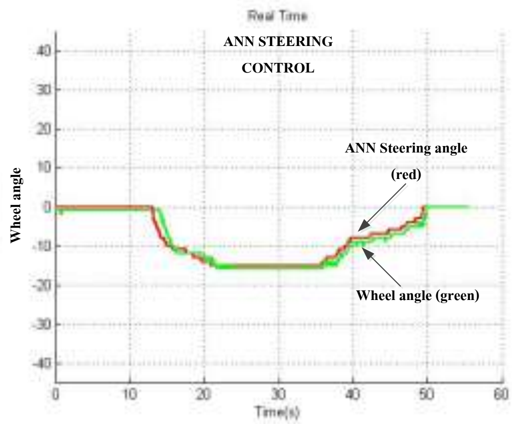
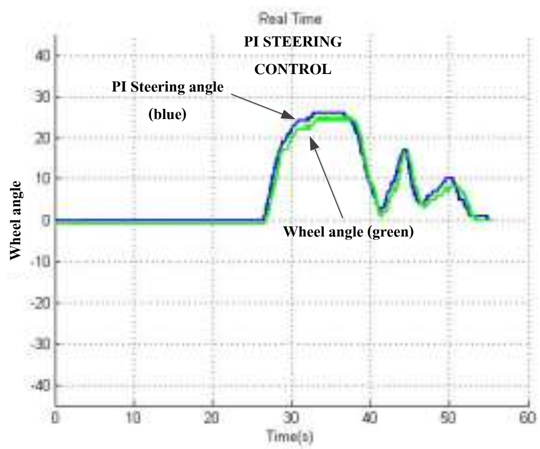


(b)

Fig. 7: Graph presenting steering control turnleft at Velocity 3 Km/h: (a) Non-use artificial neural network system type, (b) Use artificial neural system type (Green line graph is actual turn angle) (Blue line graph is turn angle with steering devices) (Red line graph is turn angle with steering devices obtained from artificial neural system)



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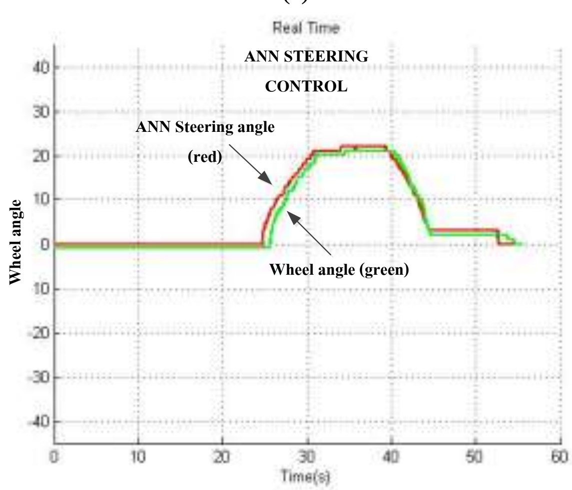
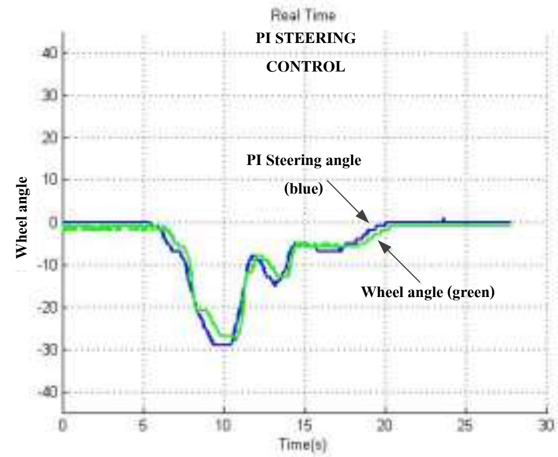


(b)

Fig. 8: Graph presenting steering control turnright at Velocity 3 Km/h: (a) Non-use artificial neural network system type, (b) Use artificial neural system type (Green line graph is actual turn angle) (Blue line graph is turn angle with steering devices) (Red line graph is turn angle with steering devices obtained from artificial neural system)



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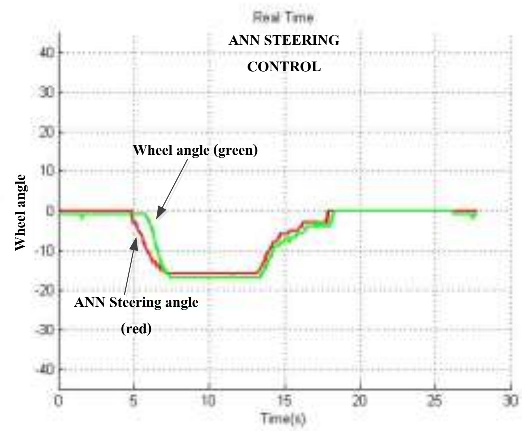
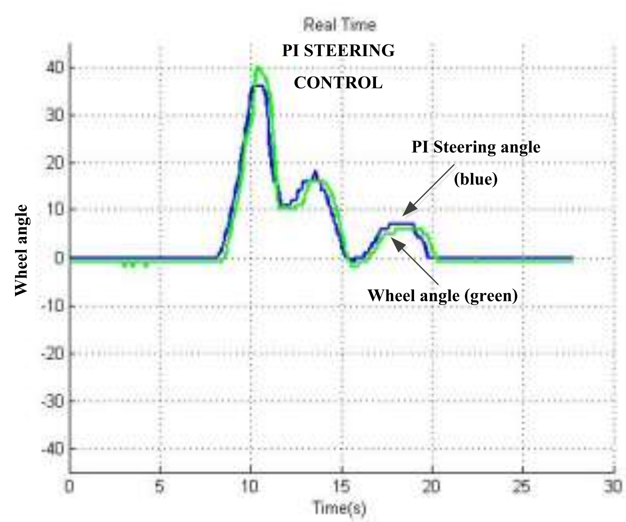


(b)

Fig. 9: Graph presenting steering control turnleft at Velocity 7 Km/h: (a) Non-use artificial neural network system type, (b) Use artificial neural system type (Green line graph is actual turn angle) (Blue line graph is turn angle with steering devices) (Red line graph is turn angle with steering devices obtained from artificial neural system)



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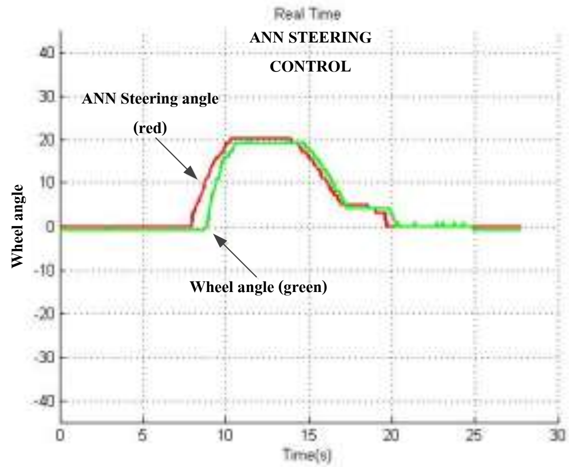


(b)

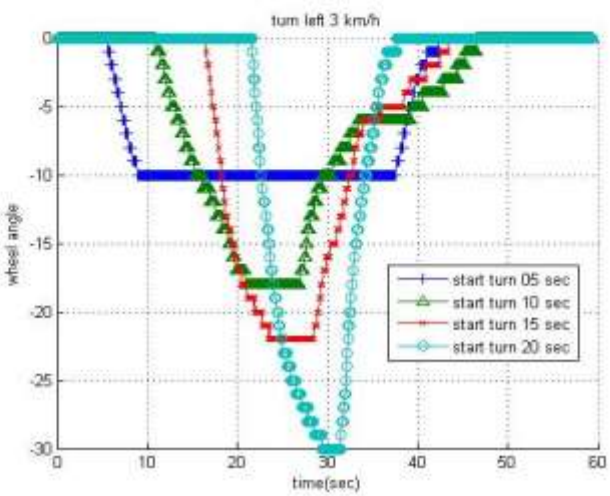
Fig. 10: Graph presenting steering control turnright at Velocity 7 Km/h: (a) Non-use artificial neural network system type, (b) Use artificial neural system type (Green line graph is actual turn angle) (Blue line graph is turn angle with steering devices) (Red line graph is turn angle with steering devices obtained from artificial neural system)

The results of driving vehicles with steering devices before coaching artificial neural network showed that steering control was quite hard and it made the vehicles sway as shown by graph (a) in Figure 7, 8, 9 and 10.

But after coaching steering control with artificial neutral network, it was found that steering control was easily made and obtained the responsive sense close to the use of genuine steering wheel as shown by graph (b) in Figure 7, 8, 9 and 10.

- Automatic steering control

The example patterns of steering control used for coaching were shown in Figure 11 (a).



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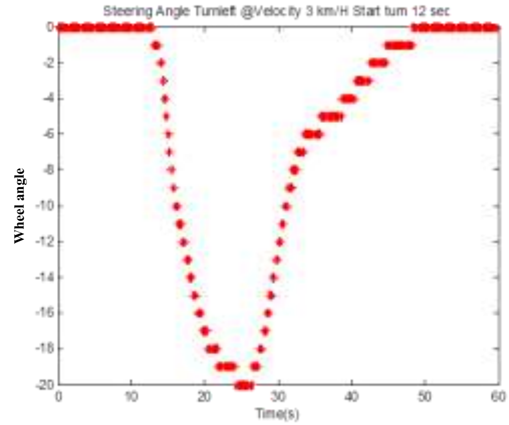

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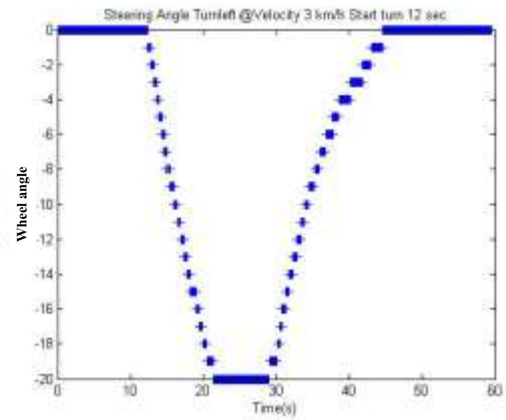


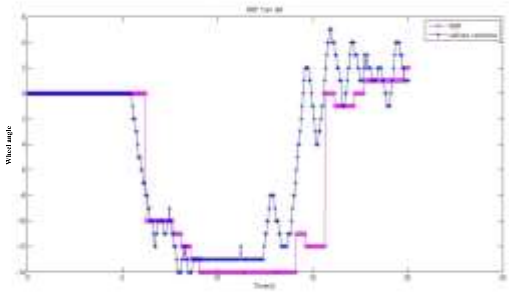
(c)

Fig. 11: (a) The example patterns of coaching steering control turnleft at velocity 3 km/h (the blue data set started turning a steering wheel at 5th second) (the green data set started turning a steering wheel at 10th second) (the red data set started turning a steering wheel at 15th second) (the blue data set started turning a steering wheel at 20th second), (b) Built by using Artificial neural network, (c) The pattern of actual steering control.

Despite the availability of only four network coaching types, the network was able to newly establish the other patterns left. When taking the example patterns of steering control behavior established by Artificial neural network to compare with the actual pattern of steering control behavior by a steering wheel, it was found that the turn angles had the most equal values at -20 degree and the patterns were similar as shown in Figure 11 (b), (c).

C.Human-Learning Steering Control Using Artificial Neural Network and Visual Servo

The results of steering control with turn angle value referred from Radial basis function test (Particularly at velocity only 7 Km/h)



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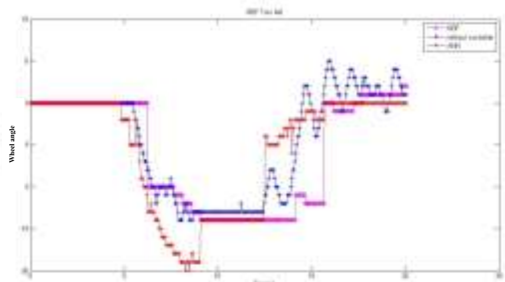

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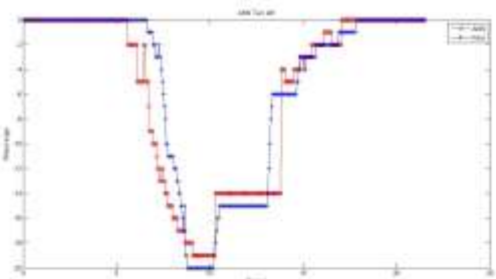
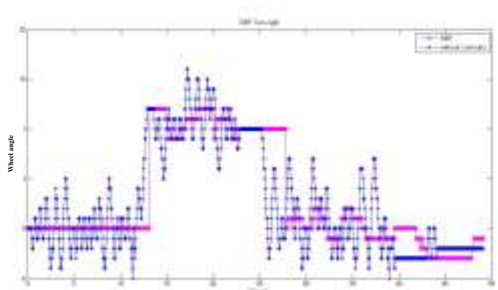


(c)

Fig. 12: Turnleft: (a) The results of steering control with steering angle referred from RBF (Pink line graph is the value of steering angle referred from RBF) (Blue line graph is the actual value of turn angle in closed control type),
(b) The results of comparison between turn angle value after network coaching and turn angle referred from RBF)
(Pink line graph is referred turn angle from RBF) (Blue line graph is actual turn angle value in closed control)
(Red line graph is turn angle value after being coached by artificial neural network),
(c) The results of actual steering control compared turn angle value comparing referred turn angle value from RBF
(Red line graph is turn angle value after being coached from artificial neural network)
(Blue line graph is actual turn angle with PI control)



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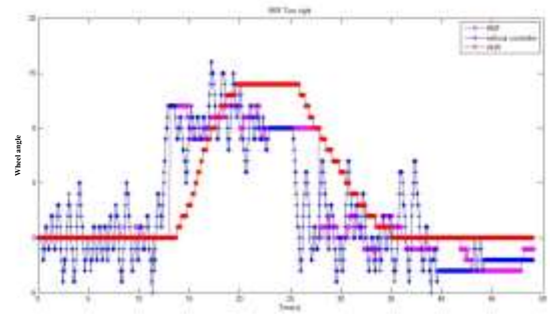

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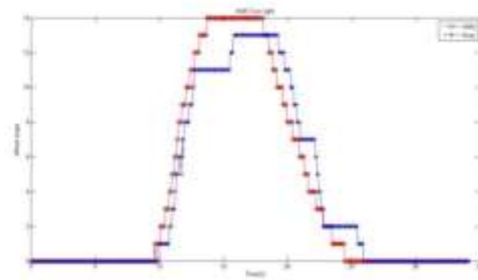

(c)

Fig. 13: Turnright: (a) The results of steering control with steering angle referred from RBF (Pink line graph is the value of steering angle referred from RBF) (Blue line graph is the actual value of turn angle in closed control type),
(b) The results of comparison between turn angle value after network coaching and turn angle referred from RBF)
(Pink line graph is referred turn angle from RBF) (Blue line graph is actual turn angle value in closed control)
(Red line graph is turn angle value after being coached by artificial neural network),
(c) The results of actual steering control compared turn angle value comparing referred turn angle value from RBF
(Red line graph is turn angle value after being coached from artificial neural network)
(Blue line graph is actual turn angle with PI control)

From the results of test, it was found that the turn angle value from RBF was quite different at the start turn affecting abruptly turns. Especially, when using closed control type without any controller, it affected more sway.

When coaching artificial neural network to adjust the turn angle value from PBF and concurrently using PI controller, the turn angle value of such turns was close to human steering control with genuine steering wheels.

V. Conclusion

This research article presented the application of artificial neural network and visual servo in learning and remembering human's vehicle steering prototype to control the steering devices and automatic operation. From usability testing by using steering devices to drive vehicles in real conditions on authentic routes, it was found that the system actually imitating human-learning steering control with steering wheel facilitated steering control with steering devices and concurrently got the responses as if it controlled steering with the genuine steering wheels. Furthermore, it was still coached with newly required steering control behavior patterns. If this steering control system is developed to extend the advantages, it will encourage used-to-drive chauffeurs with a disabled arm or hand can easily drive mentioned vehicles with a single hand. If the mentioned steering control is developed to install in the low speed tour cars which particularly run around the places such as zoo tour cars, the aforementioned handicapped people can do the mentioned career and further develop work operation for vehicle steering control for remote distances.

ACKNOWLEDGMENT

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