# Virtualized Steering Control using Kinect

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***Abstract*— Steering control or Steer-By-Wire is the technology used in automobile industry to replace traditional mechanical control system by electronic control system. The electronic control system uses some actuators and Human-Computer interface (HCI). We have used the sensing capabilities of Kinect to perform this activity. This electronic virtual control is achieved using 3D depth, skeletal tracking and microphone array mic capabilities of Kinect. A gesture and speech recognition system is built using these capabilities. In this paper, we have focused on replacing steering wheel and steering angle sensor of a Steer-By-Wire system by using Kinect and implemented gesture recognition for steering control.**

***Keywords- Kinect, Steer-by-wire, Gesture recognition, Speech recognition***

## I. INTRODUCTION

Steering control is an essential and important part in any vehicle's design. The mechanical and hydraulic controls are used in automotive industry are now replaced by electronics and computers for safety and comfort of drivers. The use of sensors or encoders to control a wide range of operations such as braking, steering, object detection, etc. is known as `by-wire' technology [5]. The implementation of electronics elevates the performance, provides safety and reliability with reduced manufacturing and operating costs [4]. Conventional steering system contains 4 major components viz. steering, steering shaft, power assist unit and gear assembly. When the driver rotates the steering, input through steering wheel is transmitted by steering shaft through gear reduction mechanism, enabling steering motion of front wheels [3]. *Steer by wire* system substitutes electronic components in place steering shaft and introduces feedback motor attached to steering wheel.

What we propose is use of Kinect as a motion sensing device which is capable of skeletal tracking (human detection) and speech recognition [15]. Here we have replaced steering wheel, angle sensor and feedback actuator of vehicle by Kinect. The purpose of this paper is to introduce a virtualized steering control which captures the hand gestures of the driver, calculates the angle from it and convert it into vehicle rotation accordingly without actual need of steering wheel.

Virtualized steering control provides main benefit to physically disabled and elderly people. Use of gesture and speech recognition assists the person driving vehicle to just specify a appropriate gesture or audio command instead of actually rotating the steering wheel. Thus these people can drive vehicles without much physical effort. Also as the Kinect is a programmable and reconfigurable device, it can be used in various vehicles with slight modifications in the code (making use of convenient gestures). Compared to other steering systems, *steer-by-wire* system provides variable steering ratio, easy assembling and enhancement of active safety. With steer-by-wire implementation, mechanical linkages are replaced by electric links, which assures actual road feel to driver.

## II. RELATED WORK

Conventional steering system has very complex interior design and poor space utilization. *Steer-by-wire* technology helps in overcoming these limitations. Conventional steering systems lack due to much change in physical modifications for changing handling characteristics. For steer-by-wire, it can be done easily through active steering interventions.

In conventional steer-by-wire system, mechanical linkage between the steering wheel and the front wheel is removed to provide vehicle stability and to assist driver for autonomous steering control.The authors of [13] augmented driver's steering command with vehicle state feedback for altering vehicle handling characteristics. The vehicle's response can be reduced or enhanced based on driver's preference and road condition. A vehicle state was accurately estimated using global positioning system and inertial navigation system sensor measurement [13]. Such a system can achieve modified handling behavior equivalent to physically changing the cornering stiffness of the front tires.

Duan Jianmin, Wang Ran and Yu Yongchuan [2] researched two control strategies viz. the immobile steering sensibility type control strategy and the yaw rate and sideslip angle control strategy [2] for handling and stability of steer-by-wire system at high speeds.

A steer-by-wire system using MATLAB environment, active steering control and the controlling scenario of integral separation PID was proposed in [7]. Their research showed that steer-by-wire controller based on Integral Partition PID Control [7] gives better dynamic characteristics than conventional controller. Also it overcomes some of the defects that conventional system can't.

To improve return ability of steer-by-wire system and reproduce realistic driving feeling, Ba-Hai Nguyen and Jee-Hwan Ryu [14] proposed a method by measuring road wheel motor's current directly. The steering torque on the rack is measured by current sensor. The current sensors are available at low costs and thus offer a simple and cost-effective solution to reproduce a real driving feel. They developed the force feedback control algorithm which not only gave a realistic driving feel, but also improved the return ability.

The release of Kinect as a gaming device by Microsoft made a remarkable effect on field of HCI. It was also cost effective as compared to the cameras and sensors. Initially it was released for XBOX gaming applications, but after the release of OpenKinect [9] and Microsoft Kinect SDKs [12], it became a platform to develop more useful applications or integrate it with a huge domain of applications other than gaming. The release of above SDKs made it easier for the academic researchers and enthusiasts to create rich experiences by using Kinect.

Robustness is an important aspect in determining hand gestures. The authors of [10] used Kinect to operate in uncontrolled environments and insensitive to hand variations and distortions. The system consist of two modules, viz. hand detection and gesture recognition. But, typical resolution of 640×480 for Kinect sensor provides problem in recognition of hand. It was eliminated using a novel shape distance metric called Finger- Earth Mover's Distance to measure the dissimilarities between different hand shapes [8].

Robert Y. Wang [1] successfully tracked the hand wearing a color glove with pre-defined custom pattern. To solve the issue of expensive and difficult to port available tracking systems, he proposed a system which is easy to use and is inexpensive. Various ways were explored to track a hand including marker based motion tracking and hand tracking with color markers. They performed the pose estimation with the help of customized glove design and sampling databases. The glove design contains pasting dense patterns of colored markers for tracking. Color glove is used for hand tracking because the bare hand gives same position on palm up and palm down whereas if we use a color glove, then we have different positions of the pattern for different poses and hence it improves the tracking accuracy [1]. The training dataset contains more than 18,000 finger positions, hence making it possible to track the hand more accurately to the fingers level.

Kinect Identity technique [11] made use of two methods viz. *biometric sign-in* and *session sign-in* for recognizing and tracking player identity. The identity system was composed of 3 techniques namely face recognition, clothing color tracking and height estimation [11]. In biometric sign in the system learns about a player's appearance over time and guesses the person when he comes in its view. In the later method, the system remembers a person for a particular session only.

## III. PROPOSED SYSTEM

The system consists of two main parts

1. Steering section
2. Wheel section.

Steering section is actually a modification in usual steer-by-wire system. Kinect replaces steering wheel, angle sensor and feedback motor in usual steer-by-wire system. Kinect performs function of both the steering wheel and the angle sensor. Microcontroller ($\mu$C) is a core part of system design and it works as an intermediate between steering section and wheel section. It contains algorithms to convert output of Kinect into the desired input for the actuator which is usually represented as voltage levels.

The other part of system viz. *wheel section* consists of actuator, pinion angle sensor and gear assembly. Kinect provides the steering actuator with input angle with the help of $\mu$C. The actuator with steering gear (rack and pinion arrangement) is responsible for corresponding turn of the tyres. The dashed rectangular portion in the system architecture (Fig. 1) depicts implementation of Kinect in steer-by-wire system. The dashed arrows indicate the flow of feedback system.

### *A. System Modules*

- *Kinect:* Kinect is a device with a RGB camera, 3D depth sensors and multi-array mic. It is capable of gesture and speech recognition. Gestures are recognized with 3D depth sensors which are capable of skeleton tracking. Kinect recognises upto 20 joints in a human body [6]. It is a highly advanced and low cost device for effective natural user interface [5]. With Kinect, hand gestures of the driver are tracked. As the driver's hands move in a 3-Dimensional plane, the corresponding co-ordinates are tracked and are converted into a angle. Gestures should be within the range of Kinect, so that positions of hand with respect to Kinect can be shown on the screen of a Windows7 tablet PC (as Kinect is currently capable of running on Windows7). A graphical display is used as an interface to user for displaying the steering actions through an image of a steering wheel and corresponding hand movements. A specific set of voice commands are implemented to make the system flexible.

- *Microcontroller:* Most of the control mechanism of a steer-by-wire system depends on the microcontroller ($\mu$C). Input to the $\mu$C is angle and output is voltage level with which the actuator should rotate. This angle is provided by Kinect. $\mu$C consists of the algorithms so as to convert the data from Kinect and give it to the motor driver. The output of the $\mu$C doesn't provide enough power (0-5 V) to rotate the actuator. So motor driver is necessary to boost it.

- *Motor Driver:* Necessary inputs to the motor are made available with the help of motor driver. Torque required for rotation of actuator is provided by motor driver. Motor driver works as a DC to DC step up power converter. It boosts the voltage level as per the requirements.
- *Servomotor:* Servomotor constitutes motor, gear head and feedback circuit. It provides steering actuation. It is attached to the remainder of the connecting shaft via flexible coupling. DC servomotor is used because it reduces noise and maximizes the motor life. It provides steering actuation. If the torque applied by the motor is sufficient to overcome the friction and road forces, wheels begin to move.

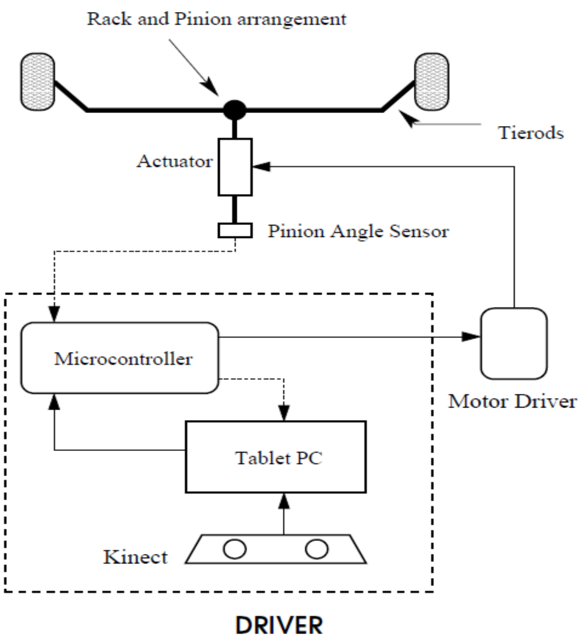


Fig. 1 System Architecture

*3.2 Determination of turning angle of wheels*

Steering ratio and lock to lock turns are used to determine angle by which wheels are to be turned. The steering ratio *a:b* indicates that *b* degree rotation of steering wheel turns tyres by *a* degree. Depending on the design of the steering system in a particular, the steering ratio may range between 12:1 to 20:1. The lock to lock turns specifies the number of rotations of steering wheel when it is rotated from a lock on one side to the lock on the other. Thus knowing the steering ratio and lock to lock turns, we determine the angle by which wheels to be turned based on the angle specified by gesture.

$$\delta = \frac{\theta \times \frac{\eta}{90}}{\mu}$$

where,

$\Theta$- Gesture angle

$\delta$ - Angle by which wheels to be turned

η – Maximum angle by which steering wheel can be rotated in one direction from center

$$\eta = \frac{\text{LTL}}{2} \times 360$$

where, LTL - lock to lock turns

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**Algorithm 1** Measuring Gesture angle

1: Enable gesture tracking module
   Command – "START THE SYSTEM"
2: GOTO 4
3: Continue until *command == RESUME* || *command == HALT*
4: **while** (command≠*STOP* **and** command≠*HALT*
   **and** *distance between hands* < *threshold* ) **do**
5: **if** (righthand.Z < lefthand.Z) **then**
6: *Z =lefthand.Z – righthand.Z*
7: *X = lefthand.X – righthand.X*
8: tan$\Theta$ = *Z/X*
9: **else if** (righthand.Z > lefthand.Z) **then**
10: *Z = righthand.Z – lefthand.Z*
11: *X = righthand.X – lefthand.X*
12: tan$\Theta$ = *Z/X*
13: **end if**
14: Pass angle $\Theta$ to $\mu$C
15: **end while**
16: **if** (*command == HALT*) **then**
17: GOTO 21
18: **else**
19: GOTO 3
20: **end if**
21: STOP

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*3.4 Workflow*

Some assistance regarding use of gestures and audio commands must be provided to the driver. Gesture recognition module of system is initiated by audio commands. Both hands of the driver are needed to be recognized by Kinect. A gesture set is built to recognize the steering gestures. After hand tracking, if distance between the two hands is greater than a threshold value, whole steering is controlled by hands. Gestures are detected as hands make virtual action of steering. The gesture system is explained in *algorithm 1*. In *algorithm 1*, lines 5-13 comes into picture only when command isn't *stop* or *halt*. X, Y and Z axis of Kinect are the axes of its depth sensor. Z axis is the distance of driver from the Kinect. As the driver moves his hands for performing virtual steering action, Z and coordinates of his hands are tracked and angle between them is measured. The calculated angle specifies the angle by which wheel needs to be turned. When driver wants to take off the hands from virtual steering, he needs to temporarily stop gesture recognition module. *STOP* command serves this purpose. Whole steering system can be turned off by *HALT* command. This command stops tracking hands and also does not respond to any commands given further.

The corresponding angle is passed to $\mu$C. It then converts the angle into a pulse (0-5 V) and sends it to motor driver. Motor driver supplies appropriate current/voltage to actuator, as voltage output from $\mu$C is very low for rotation of actuator. As actuator rotates uniformly, pinion rotates correspondingly making rack to move horizontally. Thus the tie rods move and the wheels turn by an angle.

Feedback system is used to provide feedback of actual rotation of wheels to driver (Fig 1). Actual position of wheels is measured by pinion angle sensor. Pinion angle sensor gives feedback to **µ**C. Thus the micro controller gives its output to computer application which runs Kinect and shows the effect of rotation of steering on display screen (a illusion of steering wheel on display is created which rotates). Thus even though driver applies much gesture on rough road, the wheels rotate by less degree and corresponding steering rotation is shown on screen.

### *3.5 Fault Tolerance*

If proposed steering control system fails, then there must be an alternative system which will help in avoiding danger. The steering control system ($\mu$C) can diagnose faults by detecting input and output signals and driving current of motor. If fault occurs, the control unit ($\mu$C) will stop responding by activating the fail safe relay mode. This is indicated on display screen, activating the manual steering (conventional mechanical steering). The mechanical system of steering control, which will be used only in critical situations, can be folded inside the dashboard by using telescopic cylinder. On activating fail safe mode, the telescopic cylinder can be opened to have the mechanical steering popped up. The vehicle will now be driven by conventional steering system.

## CONCLUSIONS

The virtual steering control using Kinect provides flexibility to driver and efficiently controls steering actions. Gesture recognition module is developed for giving driver, illusion of actual control of steering wheel. Accurate interaction between user gestures and mechanical components of physical steering control system is the core part of this research. Introduction of angle tracking system based on driver's gesture provides a new way to replace steering angle sensors and other mechanical components. Thus the proposed system provides a new steering control which works and feels like conventional steering system without actual steering wheel. New features like voice recognition to initiate steering, fault tolerance enhance driver flexibility and provide appropriate assistance.

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