Ergonomic evaluation of Ingress/Egress of vehicle using balance assessment approach

Simranjeet Singh, Jagjit Singh, Parveen Kalra

Abstract— Ergonomic features are needed to be introduced into the design of buses to make them highly comfortable for the driver and passengers. There is a possibility of addition of lot of ideas and techniques in the pre-manufacturing stage of products especially in case of vehicles to make them more ergonomic. Maintaining Balance of body while interacting with vehicles (e.g. during activity of Ingress/Egress etc.) is one of the key ergonomic issue. Furthermore, this area needs more exploration and easy methods of balance assessment. Center of pressure (COP) trajectory, Center of mass (COM) trajectory, Movement sway etc. are found to be the good quantitative measures of postural control and balance of human body. The methods which use the above mentioned quantitative measures can be very easy to implement with some easily available and low cost equipment like "Wii balance board and Microsoft Kinect" which are good alternatives of expensive "force plates and Vicon camera" .In present paper, the work carried out by various researchers in field of ergonomics of ingress of vehicles (especially buses) is discussed. A possible methodology of evaluation of ergonomics of ingress is also suggested.

Index Terms— Center of mass, Center of pressure, Egress, Ergonomics, Ingress, MS Kinect, SESC, WBB Nintendo

1 INTRODUCTION

THIS paper deals with the review of background research of vehicle ergonomics with a focus on Ingress/Egress activities of driver. 'Maintaining balance of human body in motion is one of the sophisticated phenomena to study. There are some important parameters essential for assessment of balance of human body. Some of the important parameters are COM, COP & COG. Center of mass (COM) is the point where whole mass of the body is supposed to be acting. COM can also be defined as a point about which a body would balance without a tendency to rotate. Center of pressure (COP) is the location on the supporting surface where the resultant vertical force vector would act if it could be considered to have a single point of application. Center of gravity (COG) is the vertical projection of COM to the ground. A shift of the COP is an indirect measure of postural sway & thus a measure of person's ability to maintain balance. All people would sway in anterior-Posterior direction (forward-Backward) & the medial-lateral direction (side to side) when they are simply standing still. This is due to the misalignment of the line of action of COP and COG, due to which the disturbing moment generates. In contrast, the physics and basic Mechanism of Dynamic balance (balance of moving body), is entirely different in comparison to that of static balance. This is due to the fact that while in motion, the body essentially needs to generate the disturbing moment for accomplishing the forward movement. COP trajectory, COM trajectory of human body are proved to be very good estimates of postural balance. With these parameters the dynamic balance of human body while interacting with vehicle can be quantified for different sets of design variables (design variables refer to the variables governing the shape and geometry of vehicle body with which human body has to maintain the dynamic or motion interaction). Now as far as the calculation of COP trajectory, COM trajectory, postural sway etc. is considered, force plates and expensive motion capture systems provide a way to directly calculate these measures. However these equipments are very costly. "Wii balance board" of Nintendo and "Kinect for windows" of Microsoft can be very low cost and reliable alternatives of the costly instruments mentioned above. MS Kinect is a motion capturing system which can produce a 3D skeleton video of the human body in motion and can help in computing center of mass of body. It can also track the values of various body joint angles during the movement of body. On the other hand Wii balance board of Nintendo is helpful in getting the position of COP of body. Now application part of assessment of balance which is relevant to current discussion is to optimize the vehicle design parameters in order to produce the safe vehicular design (especially safe for ingress and egress). This review article suggests the application of balance assessment approach in vehicle design phase so as to optimize the design for safe ingress, egress and other activities which involve the dynamic movement of human body.

- *Simranjeet Singh is currently pursuing master's degree program in Industrial Design in PEC University of technology, Chandigarh, India, PH-+919896104878. E-mail: singh.hctm@gmail.com*
- *Jagjit Singh is Asst. prof. in Production and Industrial Engg. Dept., PEC University of technology, Chandigarh, Sector 12 INDIA E-mail: Jagjit.singh@pec.ac.in.*
- *Parveen Kalra is Prof. and Head of Dept., Production and Industrial Engg. In PEC University of technology, Chandigarh. E-mail: parveenkalra@pec.ac.in.*

2 BACKGROUND RESEARCH

2.1 Review of study of Ingress/Egress

The act of ingress represents the first and one of the most important interactions of human body with vehicle. Drivers of heavy vehicles are frequently injured entering and exiting the vehicle. Getting out of a truck and bus cabin is a very complex Motion and it is very accident-prone. Drivers or firemen are frequently injured entering and exiting trucks (Patenaude et al. 2001, Lin and Cohen 1997). One of the works is associated with strategic analysis of truck cabin egress motion (Chateauroux et al, 2011). The experiment was performed to investigate the influence of COE truck architectural parameters on motion

study i.e. the variation of driver foot and hand strategies with varying design parameters of truck. Another related study dealt with the effects of BMI and stature on trajectory of driver feet (Reed et al 2009). This study leads to the important conclusion that 'Step configuration variables did not have important effects on the trajectories of feet'. Here step configuration means various important design parameters e.g. intermediate step height, intermediate step lateral position with respect to door. Chateauroux et al 2010 studied the car egress strategies adopted by some subjects. In this study, two main car egress strategies were observed: 'left leg first' and 'two legs out'. Many similar studies were focused on various behaviors of driver while ingressing and egressing the vehicle.

2.2 Review of Research in balance assessment

Research in area of human body balance has provided some important conclusions some of which are worth discussing here. Center of Pressure (COP) and Center of gravity (COG) are both related to balance in that they are dependent on the position of the body with respect to the supporting surface (Winter 1995). One of the key issue worth noting is that conditions of static (standing) and dynamic (movement) balance of body are quite different. The task in standing is to keep the body's COM safely within the base of support. However when we wish to move the body over the ground, one step or more, the criterion of balance is drastically altered because in order to accelerate our COG in forward direction, we must voluntarily initiate the start of forward fall to move the COG ahead of the base of support. The reverse is true during termination of gait where the COG must return within the base of support (winter 1995).COM trajectory is important during standing and walking since it can be used as an index for stability and fall prediction (Gonzalez et al., 2012). Furthermore, Jian et al. 1993, reported on the combined COM and COP trajectories during both initiation and termination of gait. Another related study was conducted to observe the motion of the whole body's center of mass when stepping over obstacles of different heights (Chou et al. 2001). This study investigated the effect of obstacle height on motion of the whole body's COM and its interaction with the COP of the stance foot while negotiating obstacles. This investigation showed that stepping over higher obstacles will significantly affect the motion of the whole body's COM and its interaction with the COP of stance foot. Such findings are relevant to the current discussion because Ingress activity of driver is associated with body balance while tackling with higher obstacles of window and door of buses. Driver body balance has to be quantified while ingressing the vehicle for the proper assessment of vehicle body design. As far as the cheap methods of balance assessment are considered, Wii balance board of Nintendo provides comparable data to a force plate when assessing the COP path length during standing balance trials (Clark et al, 2010). It is evident that Wii balance board (produced by Nintendo Company) can be utilized to compute the parameters which can be the quantitative measures of balance of human body. Motion capture systems also play a key role in the process of balance assessment. Motion capture systems also play a key role in the process of balance assessment. Microsoft Kinect is one of the low cost Motion Capture devices which can be a low cost solution. In short, the researchers claim that MS-Kinect and Nintendo Wii balance board provide a low cost solution for investigating multi-sensory effects on human balancing behavior (Kahori et al, 2010). The validity and usability of Wii board for plotting the COP trajectory has been verified by Young et al., 2010, Arnold et al., 2013, also. Probably a most relevant work which has proven to be most fruitful for development of methodology explained in this paper is done by cotton et.al, 2009. Cotton introduced the method of SESC (statically equivalent serial chain) as a tool for COM estimation in humans. This method is based on the works of Espiau and boulic (Espiau et al. 1998). The method, based on the concept of the Statically Equivalent Serial Chain, or SESC, requires the acquisition of force platform data and joint angles during an initial set-up phase, in which the subject under study is asked to, maintain a certain number of static postures. The data collected during this phase are used to find the parameters of the SESC which defines the position of the COM. Once the SESC is defined, the position of the COM only depends on the configuration of the SESC, which is a function of the joint angles measured on the human subject. This means that the position of the COM can be estimated from the measured values of the joint angles. SESC"s personalized COM estimation is dependent on joint angular measurements. These joint angles will be tracked by Kinect. Furthermore the integration of Kinect and Wii balance board will provide a perfect platform for proper balance assessment of body.

2.3 Possiblity of utilization of technique of balance assessment for ingress evaluation

As far as the interaction of vehicle with human body is considered, there can be several types of interactions. Ergonomic considerations may consist of seated comforts, reachability to various consoles, front traffic visibility. This review article concentrates on the ergonomics of dynamic balance of human body while entering (ingress) or exiting (egress) in or out of the vehicle. As an observation, it is quite evident that the research in 'dynamic balance assessment of human body' is at growing stage. However there are many quantitative measures like COP trajectory, COM trajectory, postural sway which may be utilized to assess the dynamic balance of human body while interacting with various synthetic environments. Once the dynamic balance is quantified by such measures, it will become quite easy to ergonomically optimize various design parameters (doorway width, first step height, sill height, floor height etc.) related to vehicle ingress. E.g. experiments may be conducted to guess which design variables will be assigned what values for an ergonomically safe and better body balance ensuring design. The need is to integrate various aspects and studies like study of 'dynamic body balance' and 'ergonomic vehicle design'. Study of dynamic body balance is quite a complex area of research, as it includes the biomechanics of body as well as the physics of balancing. There have been efforts by winter, jian, Chou and other researchers as already discussed. Basic body parameters which have been utilized for the same are COM trajectory, COP trajectory, etc. There are some specific methods to obtain the COP and COM trajectories, e.g. statically equivalent serial chain (SESC) meth-

od, Zero moment point (ZMP) method etc. SESC method particularly has been used advantageously in previous works (Gonzalez et al 2013). SESC is the experimental method to locate the COM position of the body, easily. To find the COM position we make use of the use the statically equivalent serial chain (SESC) whose end effector is located at the subject's center of mass. The orientation of each SESC link corresponds to that of the subject's limbs. The length of each link corresponds to a function of both the limbs' weight and size. For the skeleton model used these lengths are constants. Cotton et al. 2009 also utilized SESC method to estimate the position of COM for human beings in motion. Cotton estimated the COM location of a living subject using the SESC, which is a serial chain whose end effector locates the COM of any branched chain composed of rigid bodies. The theory underlying the derivation of the SESC, and justifying this technique for estimating the COM, were presented by Cotton et al. 2009, which is relevant but out of scope to explain in the current review. Two equipments worth discussing here are 1.Kinect for windows (Microsoft), and 2. Wii balance board (WBB of Nintendo). Without these simply available hardware, the application of SESC method to find the COM trajectory and COP trajectory of body is quite difficult. These are in fact the alternates for expensive laboratory grade Motion capture devices (like Vicon camera) and expensive Force plates. As evident from literature review, Kinect and WBB are good low cost alternates for finding COP and COM trajectories. Recently a study was conducted in which FP and WBB were compared on COP data that was collected simultaneously, by placing the WBB on the Force Plates (Arnold et al. 2013). Findings demonstrated that WBB is sufficiently accurate in quantifying COP trajectory, and overall amplitude and velocity during single-leg stance balance tasks. Further Dutta et al. 2013, worked on the feasibility study of low cost visual postural feedback with Wii balance board and Microsoft Kinect. Sufficient number of other studies including that of dutta finds out the good response of utilization of Kinect and WBB in assessing the balance parameters of body. Objective of Dutta et al. 2013 was: to calculate center of pressure (COP) using Wii balance board, to calculate center of mass (COM) using Microsoft Kinect sensor. It was determined that the maximum lean angle during a functional reach task can serve as a good correlate for the orientation data (from MS Kinect). After the SESC parameters are identified, only the limb orientations are required to estimate COM position. Gonzalez and colleagues highlighted with their fast calibration session that marker-less individual COM tracking could be achieved. Once the subject's SESC parameters were identified, there was no need for even COP measurements to find the COM. Therefore it is promising for in-home rehabilitation with an individualized reduced dimension model for visual feedback, providing a quantitative posture evaluation and monitoring.

2.4 Filling the research gap

The key idea is to highlight the use of Kinect and Wii balance board in conjunction, to quantify the balance ability of human body while interacting with the product. In past few years, a number of research efforts have been concentrated in investigation of vehicle ingress/egress motion strategies, causes of injuries during ingress/egress and motion simulation during the process. But none of them were focused on straight forward objective determination of balance assessment during ingress/egress & subsequently designing the vehicle with parameter values which will ensure a good body balance. There are some of the areas related to dynamic balance assessment, which need to be reviewed and researched further in order to help the vehicle developers to incorporate more ergonomic aspects into the vehicles. For example much more research is needed to investigate the conditions of dynamic stability of human body. The parameters which govern the static stability have already been well established but in case of testing the dynamic stability, we need some more clarifications. Furthermore with the existing research we have some indicators like movement sway, length of cop path, com trajectory etc., but the question asking the ideal value of those parameters is still debatable. E.g. we know that cop trajectory is the good indicator of dynamic balance, but the ideal shape of trajectory is not known to experimentalists neither it is well defined for various types of dynamic motions. The use of dynamic stability criteria is very much missing from the design criteria of vehicles. Hence, two areas of research gap as identified are – a) Ideal values of human body dynamic stability parameters & b) Application of dynamic stability parameters in improving the ergonomic aspects of vehicles. The aim of this paper is to advice a method which can be utilized in designing the more ergonomically balanced design.

3 Conclusion

After going through the works of various researchers in the fields of "Ergonomics of Ingress of vehicle" and "Validation of Kinect and WBB Hardware for balance assessment", it is concluded that Kinect and WBB hardware are claimed to provide an accurate measure of dynamic body balance parameters like COP trajectory, COM trajectory etc. Kinect of Microsoft and Wii balance board of Nintendo, although have been proved to be the good tools for assessment of body balance; they have not been used advantageously in the area of product design where there is need for manufacturing a vehicle body with an ergonomic design. Once this strategy is adopted in design phase, Vehicle ingress/egress designs can be improved ergonomically. Objective measures of balance can be established and various design combinations can be compared and finally the best ergonomic design of ingress/egress can be selected.

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