Heads-up Display based on the Real-time Multibody Simulation of a Tractor

Suraj Jaiswal*, Rafael Åman#, Jussi Sopanen*, Aki Mikkola*

* Department of Mechanical Engineering
Lappeenranta University of Technology
Yliopistonkatu 34, 53850 Lappeenranta, Finland
[suraj.jaiswal, jussi.sopanen, aki.mikkola]@lut.fi

#Valtra Inc.
Valmetinkatu 2, 44200 Suolahti, Finland
rafael.aman@agcocorp.com

Abstract

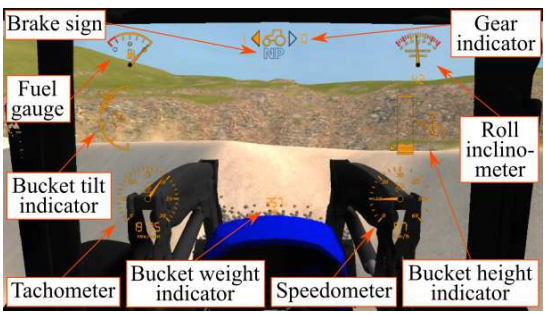
A tractor with a front-loader can interact with its environment in a number of ways. For example, it can load and transfer materials from one place to another, or it can collide with the objects of the environment. The loading and transferring of material is a common task for a tractor, and in such a situation, the driver has a limited information about the bucket position, bucket angle, and weight in the bucket. There are a number of ways to make this data available to the driver, one such approach is by using the concept of heads-up display (HUD), where the machine data are projected onto the windshield of the tractor [2].

The objective of this paper is to demonstrate a heads-up display design process based on the real-time multibody simulation of a tractor. To this end, the elements of the HUD unit, such as tachometer, speedometer, inclinometer, fuel gauge, bucket height and tilt gauge, bucket weight indicator, gear indicator, and brake sign, are analyzed by using a real-time model of a tractor. Out of these elements, the display options of bucket height gauge, bucket tilt gauge, and bucket weight indicator, are varied in the HUD unit to study their effect on the driver in achieving a task. The task is to load sand from a pile of sand and then dump it in another place on the deformable sand field [4].

A real-time tractor simulation model is used because it can be equipped with virtual sensors to make all the machine data readily available for the HUD unit. In a real tractor, this might be expensive and sometimes require extra sensors. In this study, the real-time tractor simulation model is described by using a semi-recursive multibody formulation [1]. Here, the kinematics of an open-loop system is calculated in a recursive form, from the base to the leaves, by using the classical kinematic relations. The equations of motion for the open-loop system are expressed in the relative joint coordinates by using a velocity transformation matrix. For a closed-loop system, the loop-closure constraint equations are incorporated in the equations of motion by using the penalty method [1].

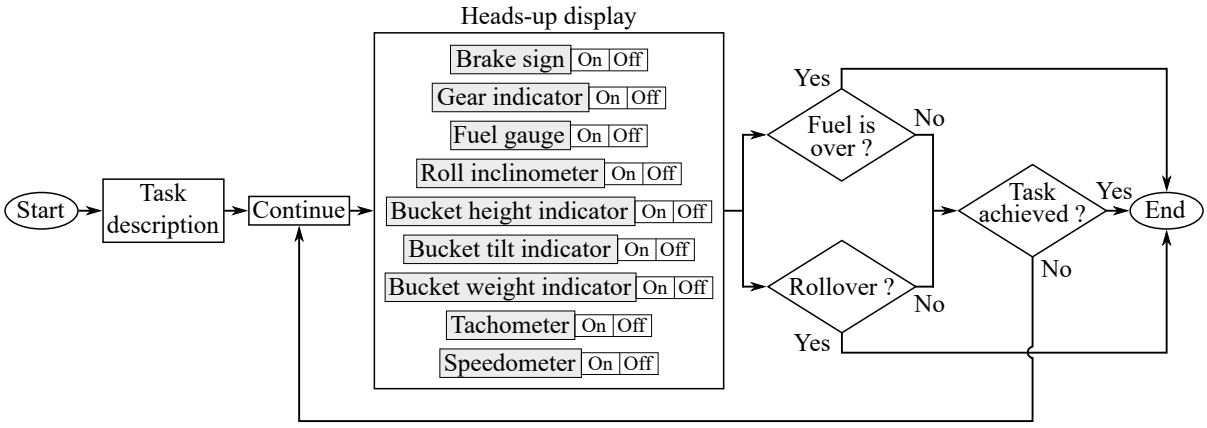
The tractor model, as shown in Figure 1a, has 13 bodies, 15 joints, 28 joint coordinates, three cut-joints, 15 loop-closure constraint equations, and nine degrees of freedom. In this study, a visualization tool [3] is used to define the scenarios, tasks, value conditions, and instructions to design the required HUD unit. The same tool can connect the scenarios and task with the tractor model to display the HUD elements on the windshield of the tractor, as shown in Figure 1b. The tool allows an easy modification of the HUD elements, and their visualizations and locations. In this study, the HUD unit is implemented by adopting the algorithm shown in Figure 2.

(a) Tractor simulation model in a deformable sand-field environment while performing the task



(b) The field of view of the driver while performing the task with HUD option-4

Figure 1: Design of heads-up display unit based on the real-time tractor simulation model


Heads-up display
Brake sign On Off
Gear indicator On Off
Fuel gauge On Off
Roll inclinometer On Off
Bucket height indicator On Off
Bucket tilt indicator On Off
Bucket weight indicator On Off
Tachometer On Off
Speedometer On Off
Start
Task description
Continue
Fuel is over ?
Yes
No
Rollover ?
Yes
No
Task achieved ?
Yes
No
End