A testbed for benchmarking state observers in multibody dynamics

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Abstract

The use of state observers in multibody system dynamics is becoming an attractive field of research in recent years. In this context, a state observer is an algorithm aimed at estimating the kinematic and dynamic state of a machine. One of the objectives pursued is to obtain a reliable estimate in spite of the difficulty of obtaining accurate models for some forces acting in practice, e.g. those acting at the tires of a car or, in general, in any part of a machine where it is not physically possible to place a sensor. There are some previous studies addressing this topic. In [1] a solution through the non-linear Extended Kalman filter (EKF) is proposed to estimate the state of a real vehicle, although real-time performing was not achieved. That fact encouraged the effort in testing new approaches focusing not only in their accuracy but also on their computational cost. In [2] we analyzed different alternatives and presented them as a benchmark framework. However, the cases of studies only rely on simulations. In other works, such as [3, 4], experimental plants has been used as an off-line ground-truth. In the present work we have developed a testbed that incorporates a software framework capable of performing the estimations in real-time. The real prototype is combined with a software architecture called OpenMORA [5] which has already been used successfully on systems of different nature [6, 7]. In Figure 1 a schematic of this testbed is presented.

The linkage incorporates a disk made of iron which is used as a crank in order to maximize its inertia. This element is connected to a programmable incremental 10000 pulses per revolution (ppr) encoder whose Z index calibration ensures the repeatability of experiments. The coupler consists of a light bar built in aluminum where the first 6 axes inertial measurement unit (IMU) is placed. Finally, the rocker consists of a solid aluminum bar incorporating another IMU, coupled to a shaft attached to a 360 ppr encoder. Both crank and rocker axles are inserted in support bearings fixed to the chassis. For collecting the information of the four sensors a laptop is placed in the central part of the chassis. In order to manage the reading from the encoders, a PhidgetEncoder Highspeed 4-Input data acquisition board is connected to laptop via USB. On the other hand, the two IMUs communicate directly with the laptop through USB. The software architecture employs a publication/subscription pattern, in which several independent

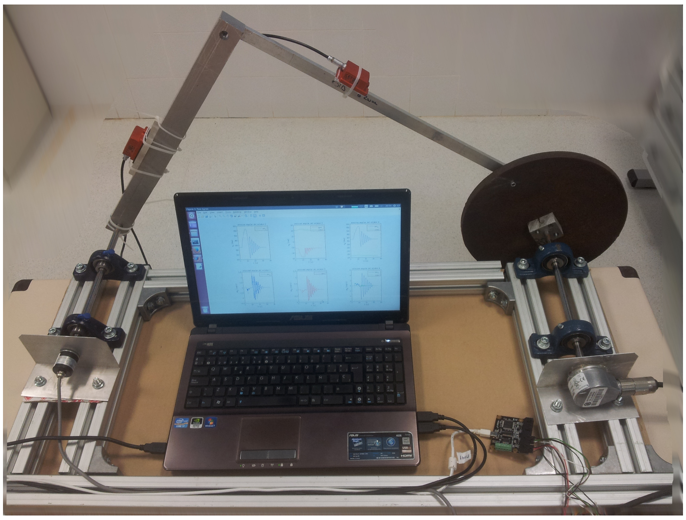

Figure 1: Testbed for real experiments.

processes also called modules are executed in parallel. The sensors are managed by two of these modules, each of which communicates with two sensors simultaneously. The first of these modules is responsible for the encoders.The buffer is read every 10 ms and this module publishes variables corresponding to the position and angular velocity of the crank and the rocker, respectively.
The second module publishes the IMUs measurements, which correspond to the acceleration in the three axis of the points where each unit is placed along with the angular position and velocity of both the coupler and the rocker links. This module operates at a frequency of 100 Hz. The graphical user interface is achieved by means of another module called ScopeLogger. Finally, the software frame incorporates the toolbox_mbe, a library programmed in C++ which simplifies the implementation of the different estimators to be tested.

References

[1] J. Cuadrado, D. Dopico, J. A. Perez, R. Pastorino. Automotive observers based on multibody models and the extended Kalman filter. Multibody System Dynamics, Vol. 27, No. 1, pp. 3–19, 2012.

[2] J. Torres, J. Blanco, E. Sanjurjo, M. Naya, A. Giménez. Towards benchmarking of state estimators for multibody dynamics. In The 3rd Joint International Conference on Multibody System Dynamics. The 7th Asian Conference on Multibody Dynamics, pp. 261–262, Busan, Korea, 2014.

[3] R. Pastorino, J. Cuadrado, D. Richiedei. State estimation using multibody models and unscented Kalman filters. In The 2nd Joint International Conference on Multibody System Dynamics, pp. 245–246, Stuttgart, Germany, 2012.

[4] J.-L. Blanco, J.-L. Torres-Moreno, A. Giménez-Fernández. Multibody dynamic systems as Bayesian Networks: applications to robust state estimation of mechanisms. Multibody System Dynamics, in press.

[5] MAPIR lab (University of Málaga), ARM group (University of Almería). Open Mobile Robot Arquitecture (OpenMORA). http://sourceforge.net/projects/openmora, 2014.

[6] J. G. Monroy, J.-L. Blanco, J. González-Jiménez. An Open Source Framework for Simulating Mobile Robotics Olfaction. In 15th International Symposium on Olfaction and Electronic Nose (ISOEN), ISOCS (International Society for Olfaction and Chemical Sensing), 2013.

[7] J.-L. Torres-Moreno, J.-L. Blanco, M. Bellone, F. Rodriguez, A. Giménez-Fernández, G. Reina. A proposed software framework aimed at energy-efficient autonomous driving of electric vehicles. In International Conference on Simulation, Modelling, and Programming for Autonomous Robots (SIMPAR 2014), Vol. 8810 of Lecture Notes in Artificial Intelligence, Springer, 2014.