Huygens probe entry trajectory reconstruction using Kalman filtering

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Space probes entering into planetary atmosphere can be used for in-situ study of its structure. During the entry phase aerodynamic forces exerted by a probe are related to atmospheric density. As a consequence acceleration measured by on-board sensor can be used to derive atmospheric density, pressure and temperature profiles as well as the probe trajectory. Huygens probe that has entered Titan's atmosphere is a perfect example of this technique. In this work acceleration data acquired by HASI (Huygens Atmospheric Structure Instrument) have been used to reconstruct probe trajectory and Titan's atmospheric structure at altitudes from 1570 km down to 160 km, where no direct measurements was possible due to the presence of the heatshield.
Initial attitude conditions have been estimated from accelerometers measurements before atmospheric entry, confirming probe spin around 7 rpm.
Entry state at 1570 km is obtained by comparing simulated deceleration profile with the one retrieved from accelerometer data and correcting the nominal entry vector as given by Huygens Project. A very accurate six degree of freedom model of the entry phase of the mission has been developed and a new reconstruction technique based on Kalman filtering is presented.
The algorithm gives an estimation of position, velocity, angular rate and attitude of the probe and of the physical parameters of the atmosphere. Drag forces acting on the probe depend strongly on atmospheric density and probe velocity: this relation allows to update the preflight atmospheric density and pressure profiles based on accelerometer measurements.
Reconstructed trajectory is consistent with profiles obtained from other approaches and preflight models. Used technique produces also an estimate of the probe attitude which is consistent with measured data.