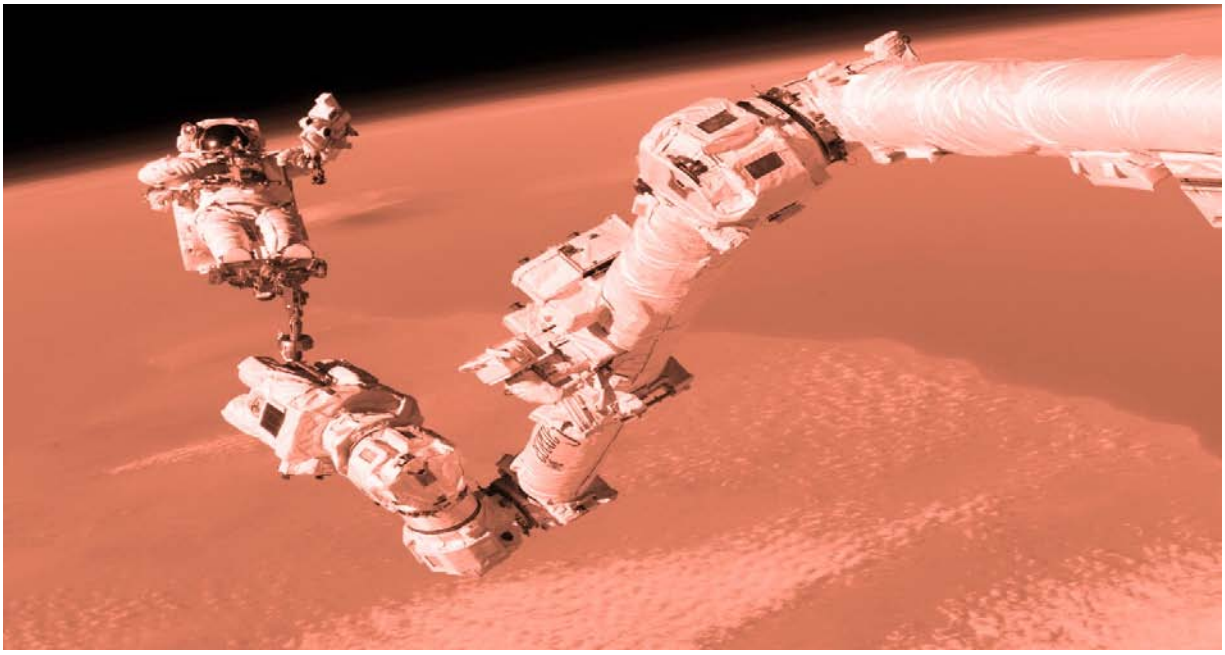
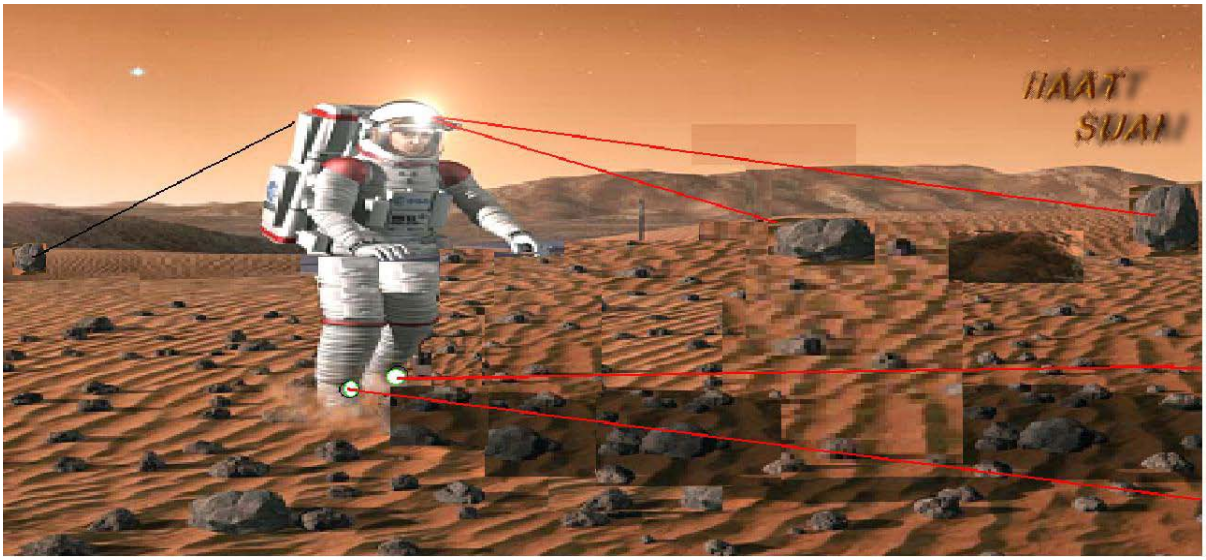
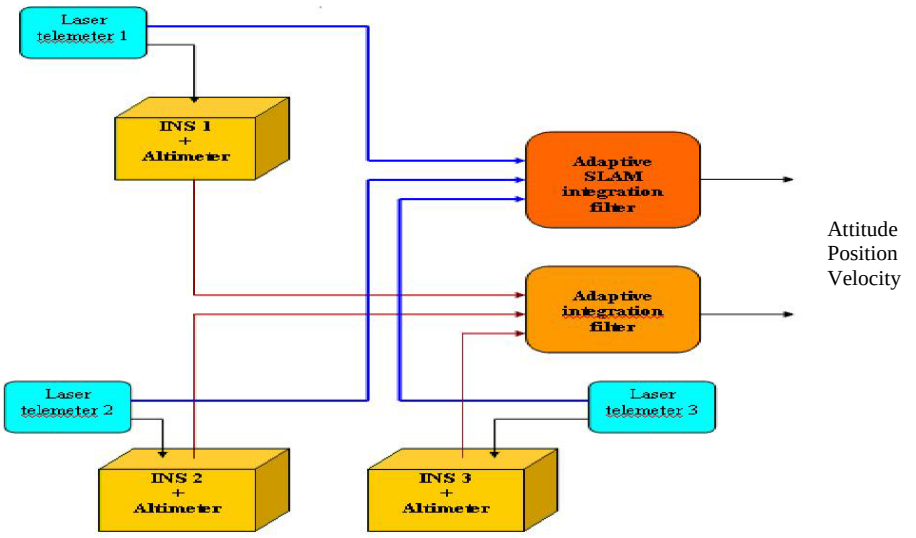
Project 6. Astronaut Navigation System for Mars Planet Exploration



Original solutions for navigation on the surface of Mars planet, especially applicable to astronauts, are proposed and investigated. Without satellites positioning system, it is proposed an autonomous localization and navigation system with multiple solutions, based only on inertial measurement units and laser telemeters, it permits to astronauts to navigate both in known and unknown environment.





The estimation of the position of astronauts is done using non linear adaptive filters as the extended Kalman filter, the sigma point Kalman filters, divided differences Kalman filters and also using particle variant non linear filters. The new approach answers the problem of how to extend the existing solutions of localization and Navigation on the earth to Mars surface, according to changes of the magnetic field, gravity and orbital parameters. The IIAAT is engaged in this new field of research and expect seriously to realize the first experimental model for Astronaut space suit.

Mathematical model :

The estimation is based on inertial sensors such as accelerometers and gyrometers.

IMU's

$$Nimu2(k+1) = Nimu2(k) + T.Vimu2(k).Cos(\Psi_k imu2) + w_N(k)$$
$$Eimu2(k+1) = Eimu2(k) + T.Vimu2(k).Sin(\Psi_k imu2) + w_E(k)$$
$$\Psi imu2(k+1) = \Psi imu2(k) + \omega imu2(k).T + w_\Psi(k)$$

$$Nimu1(k+1) = Nimu1(k) + T.Vimu1(k).Cos(\Psi_k imu1) + w_N(k)$$
$$Eimu1(k+1) = Eimu1(k) + T.Vimu1(k).Sin(\Psi_k imu1) + w_E(k)$$
$$\Psi imu1(k+1) = \Psi imu1(k) + \omega imu1(k).T + w_\Psi(k)$$

$$Nimu3(k+1) = Nimu3(k) + T.Vimu3(k).Cos(\Psi_k imu3) + w_N(k)$$
$$Eimu3(k+1) = Eimu3(k) + T.Vimu3(k).Sin(\Psi_k imu3) + w_E(k)$$
$$\Psi imu3(k+1) = \Psi imu3(k) + \omega imu3(k).T + w_\Psi(k)$$

Direct and Indirect estimation techniques are applied:

Direct model:

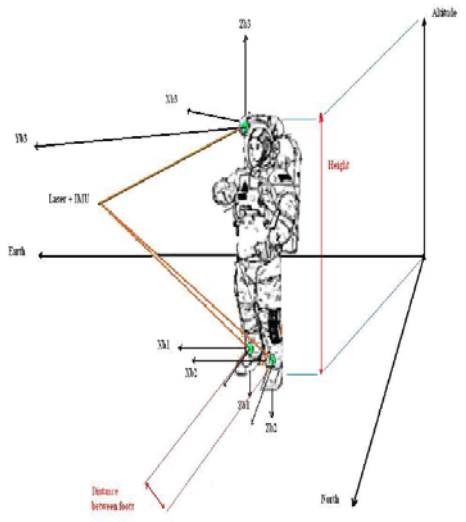
$$\begin{bmatrix} \mathrm{p}_n(k) \\ \mathrm{v}_n(k) \\ \psi_n(k) \end{bmatrix} = \begin{bmatrix} \mathrm{p}_n(k-1) + \mathrm{v}_n(k-1)\Delta t \\ \mathrm{v}_n(k-1) + \{\mathrm{C}_n^b(k-1)[\mathrm{f}_b(k) + \delta \mathrm{f}_b(k) + g^n]\}\Delta t \\ \psi_n(k-1) + \mathrm{E}_b^n(k-1)[\omega^b(k) + \delta\omega^b(k)]\Delta t \end{bmatrix} + \begin{bmatrix} \mathrm{w}_{p^n}(k) \\ \mathrm{w}_{v^n}(k) \\ \mathrm{w}_{\psi^n}(k) \end{bmatrix}$$

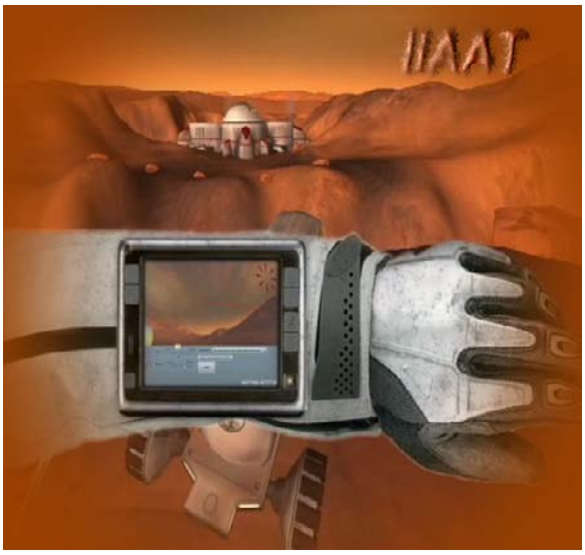
Indirect model:

$$\begin{bmatrix} \delta\dot{p}_f \\ \delta\dot{v}_f \\ \dot{\psi}_f \\ \dot{b}_{a_f} \\ \dot{b}_{g_f} \end{bmatrix} = \begin{bmatrix} F_{pp} & I & 0 & 0 & 0 \\ F_{vp} & F_{vv} & F_{v\psi} & A^T & 0 \\ 0 & 0 & F_{\psi\psi} & 0 & -A^T \\ 0 & 0 & 0 & -1/\tau_a & 0 \\ 0 & 0 & 0 & 0 & -1/\tau_b \end{bmatrix} \begin{bmatrix} \delta p_f \\ \delta v_f \\ \psi_f \\ b_{a_f} \\ b_{g_f} \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 \\ A^T & 0 & 0 & 0 \\ 0 & -A^T & 0 & 0 \\ 0 & 0 & I & 0 \\ 0 & 0 & 0 & I \end{bmatrix} \begin{bmatrix} w'_a \\ w'_g \\ w_{ba} \\ w_{bg} \end{bmatrix}$$

Solutions for Filter's update (KF, EKF, SPKF, DDF and PF):

1. **ZUPT**
2. **RDUPT**
3. **RVUPT**
4. **HUPT & RHUPT (Height Update & Relative Height Update)**





References :

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2. Benzerrouk.H, Nebylov.A, Yatsevitch. G, *Intelligent Algorithms for Navigation on the surface of MarsPlanet, IFAC ICONS,Istanbul Turkey,Special session2 ,"intelligent Control Systems in Aerospace"- 2009.*

3. Benzerrouk.H, Nebylov.A, Yatsevitch. G, *Original Solutions for Localization and Navigation on the surface of Mars Planet, IEEE Aerospace Conference ,Big Sky USA-2010.*

4. **. Benzerrouk.H, Nebylov.A, Yatsevitch. G**, *Smart Algorithms for Localization and Navigation on the surface of Mars Planet, Based on Natural Constraints 18th IFAC Symposium on Automatic Control in Aerospace ACA'2010. 6 - 10 September 2010.*