

Online Estimation of Inertial Parameters Using a Recursive Total Least-Squares Approach

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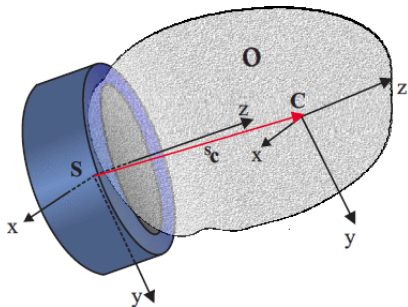
Nomagic – Robotic Seminar

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- 2007 On-line rigid object recognition and pose estimation based on inertial parameters (D. Kubus, T. Kroger)
- 2008 On-Line Estimation of Inertial Parameters Using a Recursive Total Least-Squares Approach (D. Kubus, T. Kroger)
- 2014 Combining visual and inertial features for efficient grasping and bin-picking (D. Kubus, I. Weidauer)
- 2018 Real-Time Identification of Robot Payload using a Multirate Quaternion-based Kalman Filter and Recursive Total Least-Squares (S. Farsoni, C. Talignani Landi)

Definition of the problem

- F/T sensor Gamma measuring:
 - force ${}^S f$,
 - torque ${}^S \tau$,
 - in the sensor frame S .
- Payload grasped by the suction tool:
 - mass m ,
 - center of mass ${}^S c$,
 - moment of inertia ${}^S I$,
 - linear acceleration ${}^S a$,
 - angular acceleration ${}^S \alpha$,
 - angular velocity ${}^S \omega$,
 - gravity ${}^S g$.



Newton-Euler Approach

The motion of the body due to external forces is described by the two equations:

$${}^S f = m^S a - m^S g + {}^S \alpha \times m^S c + {}^S \omega \times ({}^S \omega \times m^S c) \quad (1)$$

$${}^S \tau = {}^S I {}^S \alpha + {}^S \omega \times ({}^S I {}^S \omega) + m^S c \times {}^S a - m^S c \times {}^S g \quad (2)$$

also in matrix form:

$$\begin{pmatrix} {}^S f \\ {}^S \tau \end{pmatrix} = {}^S A({}^S a, {}^S \alpha, {}^S \omega, {}^S g) {}^S \varphi \quad (3)$$

with ${}^S \varphi = (m, m^S c_x, m^S c_y, m^S c_z, {}^S I_{xx}, {}^S I_{xy}, {}^S I_{xz}, {}^S I_{yy}, {}^S I_{yz}, {}^S I_{zz})^T$

Estimation of the sensor offsets

Strain gage force/torque sensors typically show offsets that would deteriorate the estimation:

- Zeroing the sensor value at a known sensor orientation,
- Directly estimating the sensor offsets.

The number of parameters to estimate increase from 10 to 16:

$${}^S\varphi_{ext} = [f_{O_x}, f_{O_y}, f_{O_z}, {}^S\varphi]^T \quad (4)$$

$${}^S A_{ext} = [\mathbb{I}_{6 \times 6} {}^S A] \quad (5)$$

(drift effects can be neglected since the estimation duration is less than 3s)

Optimisation problem

During the motion of the payload, M ${}^S A_{ext}$ matrices are compiled at subsequent instants of time:

$${}^S A_{\Xi} = [{}^S A_1^T {}^S A_2^T \dots {}^S A_M^T]^T \quad (6)$$

$$\begin{pmatrix} s_f \\ s_{\tau} \end{pmatrix}_{\Xi} = \left[\begin{pmatrix} s_f \\ s_{\tau} \end{pmatrix}_1^T \begin{pmatrix} s_f \\ s_{\tau} \end{pmatrix}_2^T \dots \begin{pmatrix} s_f \\ s_{\tau} \end{pmatrix}_M^T \right]^T \quad (7)$$

The optimization problem is the following:

$$\begin{aligned} & \underset{s_{\varphi}}{\text{minimize}} \quad \left\| \begin{pmatrix} s_f \\ s_{\tau} \end{pmatrix}_{\Xi} - {}^S A_{\Xi} s_{\varphi} \right\| \\ & \text{subject to} \quad m \geq 0 \\ & \quad \quad \quad c_z \geq 0 \end{aligned}$$

Recursive Total Least-Squares (RTLS) Method

