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

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References

2007 On-line rigid object recognition and pose estimation based on inertial parameters (D. Kubus, T. Kroger)

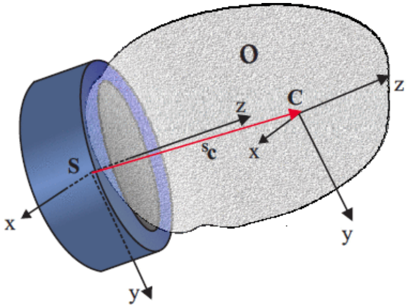
2008 On-Line Estimation of Inertial Parameters Using a Recursive Total Least-Squares Approach (D. Kubus, T. Kroger)

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:

$$
\begin{aligned}
{}^S f &= m {}^S a - m {}^S g + {}^S \alpha \times m {}^S c + {}^S \omega \times ({}^S \omega \times m {}^S c) && (1)\\
{}^S \tau &= {}^S I {}^S \alpha + {}^S \omega \times ({}^S I {}^S \omega) + m {}^S c \times {}^S a - m {}^S c \times {}^S g && (2)
\end{aligned}
$$

also in matrix form:

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

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:

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

$$^{S}A_{ext} = [\mathbb{I}_{6\times 6}\, {}^{S}A] \tag{5}$$

(drift effects can be neglected since the estimation duration is less than $3\mathrm{s}$)

Optimisation problem

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

$$ {}^SA_{\Xi} = [{}^SA_1^T\, {}^SA_2^T \ldots {}^SA_M^T]^T \tag{6} $$

$$ \begin{pmatrix} {}^Sf \\ {}^S\tau \end{pmatrix}_{\Xi} = \left[\begin{pmatrix} {}^Sf \\ {}^S\tau \end{pmatrix}_1^T \begin{pmatrix} {}^Sf \\ {}^S\tau \end{pmatrix}_2^T \cdots \begin{pmatrix} {}^Sf \\ {}^S\tau \end{pmatrix}_M^T \right]^T \tag{7} $$

The optimization problem is the following:

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

Recursive Total Least-Squares (RTLS) Method

RTLS

End frame