A centre manifold of your dynamical system

A. J. Roberts, University of Adelaide
`http://orcid.org/0000-0001-8930-1552`

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Generally, the lowest order, most important, terms are near the end of each expression.

off echo;

Specified dynamical system

$$\dot{x}_1 = -x_1 y_1 \varepsilon$$

$$\dot{y}_1 = w_0 \sigma + x_1^2 \varepsilon - 2y_1^2 \varepsilon - y_1$$

off echo;

Time dependent centre manifold coordinates

$y_1 =$
$-2X_1^2 \mathrm{e}^{-1t} \star \mathrm{e}^{-1t} \star w_0 \ \sigma \varepsilon^2 + 2X_1^2 \mathrm{e}^{-1t} \star w_0 \ \sigma \varepsilon^2 + X_1^2 \varepsilon + O(\varepsilon^4, \sigma^2) + \mathrm{e}^{-1t} \star w_0 \ \sigma$

$x_1 = -2X_1^3 \mathrm{e}^{-1t} \star \mathrm{e}^{-1t} \star w_0 \ \sigma \varepsilon^3 + X_1 \mathrm{e}^{-1t} \star w_0 \ \sigma \varepsilon + X_1 + O(\varepsilon^4, \sigma^2)$

Result centre manifold DEs

$\dot{X}_1 = -4X_1^3 \mathrm{e}^{-1t} \star \mathrm{e}^{-1t} \star w_0 \ w_0 \sigma^2 \varepsilon^4 - X_1^3 \varepsilon^2 + 2X_1 \mathrm{e}^{-1t} \star w_0 \ w_0 \sigma^2 \varepsilon^2 - X_1 w_0 \sigma \varepsilon + O(\varepsilon^5, \sigma^3)$