Commentary for the sensitivity and stability analysis by S-system

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1 Objectives

Sensitivity analysis shows how a biochemical system responds to perturbations or uncertainties. S-system is able to solve the various sensitivities and stability of the system at the steady state in symbolic form. The checkdae module converts ordinary differential equations (TT, CMA, GMA, and MM) into S-system with the coefficient function for calculating the kinetic order and kinetic rate constants at the steady state. The concentrations at the steady state must be solved before this analysis. The checkdae module carries out the sensitivity and stability analysis of S-system.

2 Function

See the commentary of S-system.

2.1 Creation of S-system parameter file

See the commentary of S-system. Following calculating the coefficients of S-system, the S-system parameter file is created. The S-system parameters provide the values of the coefficients at the steady state for the S-system user function.

2.2 Sensitivity analysis

See the commentary of S-system. The coefficient matrix of S-system is created to solve the various kinds of the sensitivities.

2.3 Stability analysis

See the commentary of S-system. After the coefficient matrix of the system is created, the eigenvalues of the matrix are calculated by the Hessenberg QR method.

3 Input/Output Specification

3.1 Input specification

The input files necessary for calculating the sensitivity and stability are the S-system user function that has been obtained at the steady state, and the S-system parameter file. Their specifications are described in detail elsewhere.

3.1.1 S-system parameter file

The parameter file necessary for simulating S-system is output as follows,

```
##### Model ################
N_VAR     ;      3; # num of variables(all)
N_ALGEBR;      0; # num of variables(all)

#Y_START ; index; initial_value; tag #comment
Y_START ;      1;    6.7000e-02; X1              #
Y_START ;      2;    4.6501e-01; X2              #
Y_START ;      3;    1.5000e-01; X3              #

#PARAM;name;index;val;val_start;num_survey;D/R/S;change-val;GA_min;GA_max;tag #comment
PARAM      ;constantPlayer;      1;    1.0000e+01;;0;D;;;; X4              #
```

```
PARAM     ;constantPlayer;     2;    5.0000e+00;;0;D;;;; X5            #
PARAM     ;constantPlayer;     3;    3.0000e+00;;0;D;;;; X6            #
PARAM     ;constantPlayer;     4;    4.0000e+01;;0;D;;;; X7            #
PARAM     ;constantPlayer;     5;    1.3600e+02;;0;D;;;; X8            #
PARAM     ;constantPlayer;     6;    2.8600e+00;;0;D;;;; X9            #
PARAM     ;constantPlayer;     7;    4.0000e+00;;0;D;;;; X10           #
PARAM     ;kplus              ;     1;    7.7884e-02;;0;D;;;; alpha_1     #
PARAM     ;kplus              ;     2;    5.8501e-01;;0;D;;;; alpha_2     #
PARAM     ;kplus              ;     3;    7.9346e-04;;0;D;;;; alpha_3     #
PARAM     ;kminus             ;     1;    1.0627e+00;;0;D;;;; beta_1      #
PARAM     ;kminus             ;     2;    7.9346e-04;;0;D;;;; beta_2      #
PARAM     ;kminus             ;     3;    1.0588e+00;;0;D;;;; beta_3      #
PARAM     ;g                  ;     1;    6.6000e-01;;0;D;;;; gi_1_1      #
PARAM     ;g                  ;     2;    1.0000e+00;;0;D;;;; gi_1_3      #
PARAM     ;g                  ;     3;    9.5000e-01;;0;D;;;; gd_2_1      #
                         ---omission---
PARAM     ;h                  ;     5; -3.0600e+00;;0;D;;;; hd_2_3      #
PARAM     ;h                  ;     6;    1.0000e+00;;0;D;;;; hi_2_5      #
PARAM     ;h                  ;     7;    3.0000e-01;;0;D;;;; hd_3_3      #
PARAM     ;h                  ;     8;    1.0000e+00;;0;D;;;; hi_3_6      #

#T_EVENT ; name; index; time; value; #comment

######## Don't edit the following lines. ######
PARAM_NAME ;constantPlayer    #
PARAM_NAME ;kplus              #
PARAM_NAME ;kminus             #
PARAM_NAME ;g                  #
PARAM_NAME ;h                  #
```

3.2 Output specification

3.2.1 S-system sensitivity and stability result file

Following the analytical solution, the various sensitivities and stability are provided as follows.

```
##### Fri Mar 28 16:14:40 2003 #####

# Logarithmic Gains and Sensitivities.

# The following data is the things when calculating STD.
##### Fri Mar 28 16:14:39 2003 #####

Solver No.                :            11
Param Survey              :             0
NR_TRIAL                  :            20
NR_TOL_F                  : 1.000E-15
NR_TOL_X                  : 1.000E-15
---omission---
h[ 8]       =    1.0000e+00             #hi_3_6

# Below this line is as a result of sensitivity analysis etc.

$ Fluxes $
index,       y value ,          Flux
       1,     6.700e-02,     1.068e+00, #X1
       2,     4.650e-01,     1.714e+00, #X2
       3,     1.500e-01,     1.714e+00, #X3
```

$ Eigenvalues $

No.	Real	Imaginary
1	-2.508e+01	0.000e+00
2	-1.037e+00	0.000e+00
3	-5.281e+01	0.000e+00

$ Logarythmic Gains of Metabolites $

param/var	y[1]	y[2]	y[3]
constantPlayer[1]	8.283e-01	1.029e+00	1.216e+00
constantPlayer[2]	3.100e-01	8.038e-01	9.497e-01
constantPlayer[3]	1.255e+00	1.560e+00	1.843e+00
constantPlayer[4]	-6.545e-01	-2.298e-03	-2.716e-03
constantPlayer[5]	-8.648e-02	-2.243e-01	3.264e-02
constantPlayer[6]	-8.821e-01	-2.288e+00	-3.000e+00
constantPlayer[7]	3.681e-01	9.545e-01	1.128e+00

$ Sensitivities of Metabolites with respect to rate constants $

param/var	y[1]	y[2]	y[3]
alpha[1]	1.255e+00	1.560e+00	1.843e+00
alpha[2]	9.686e-01	2.512e+00	2.968e+00
alpha[3]	8.821e-01	2.288e+00	3.000e+00

$ Sensitivities of Metabolites with respect to kinetic orders $

param/var	y[1]	y[2]	y[3]
g[1]	1.907e+00	2.370e+00	2.800e+00
g[2]	1.379e+00	1.713e+00	2.024e+00
- - - - - omission - - - - -			
h[7]	5.020e-01	1.302e+00	1.708e+00
h[8]	-9.269e-01	-2.404e+00	-3.153e+00

$ Logarythmic Gains of Fluxes $

param/flux	v[1]	v[2]	v[3]
constantPlayer[1]	6.600e-01	3.649e-01	3.649e-01
constantPlayer[2]	0.000e+00	2.849e-01	2.849e-01
constantPlayer[3]	1.000e+00	5.528e-01	5.528e-01
constantPlayer[4]	0.000e+00	-8.147e-04	-8.147e-04
constantPlayer[5]	0.000e+00	9.791e-03	9.791e-03
constantPlayer[6]	0.000e+00	9.987e-02	9.987e-02
constantPlayer[7]	0.000e+00	3.383e-01	3.383e-01

$ Sensitivities of Fluxes with respect to rate constants $

param/var	v[1]	v[2]	v[3]
alpha[1]	1.000e+00	5.528e-01	5.528e-01
alpha[2]	0.000e+00	8.903e-01	8.903e-01
alpha[3]	0.000e+00	-9.987e-02	9.001e-01

$ Sensitivities of Fluxes with respect to kinetic orders $

param/var	v[1]	v[2]	v[3]
g[1]	1.520e+00	8.401e-01	8.401e-01
g[2]	1.099e+00	6.073e-01	6.073e-01
g[3]	0.000e+00	-2.286e+00	-2.286e+00
g[4]	0.000e+00	2.795e-01	2.795e-01
- - - - - omission - - - - -			
h[6]	-3.170e-16	5.387e-01	-4.374e+00
h[7]	-1.545e-17	-5.684e-02	-5.684e-02
h[8]	2.851e-17	1.049e-01	1.049e-01