Simulink and Production - Financial Systems

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The production and financial systems pertain to the most complicated dynamical systems. The mathematical models are possible to use for these purposes. The simulation plays an important role in searching of the production and financial processes. The simulation is the process of attempting to build up the model of the studied system and use it for the purposes of the system behaviour prediction. The aim is to build up the simplest model representing the behaviour of the actual model with satisfactory accuracy. The mathematical model will be presented by the differential equation in the form of

$$My''(t) + By'(t) + Dy(t) = 0,$$

where M is the inertial coefficient, B is the dissipative coefficient and D is the directive coefficient. The following table shows this analogy not only for mechanical, hydraulic and electrical system, but for production and financial systems, too.

System	Mechanical M	Hydraulic H	Electrical E	**Production P**	**Financial F**
Force	Force LMT^{-2}	Pressure $L^{-1}MT^{-2}$	Voltage $L^2MT^{-3}I^{-1}$	Production force $L^2MT^{-2}p^{-1}$	Financial force $L^2MT^{-2}\$^{-1}$
Effort	Deviation L	Volume L^3	Charge IT	Product p	Capital $
Flow	Speed LT^{-1}	Flow $L^{-3}T^{-1}$	Current I	Productivity pT^{-1}	Capital flow $\$T^{-1}$
Dissipation B	Mech. dis. coef. MT^{-1}	Hydr. dis. coef. $L^{-4}MT^{-1}$	El. dis. coef. $L^2MT^{-3}I^{-2}$	Prod. dis. coef. $L^2MT^{-1}p^{-2}$	Fin. dis. coef. $L^2MT^{-1}\$^{-2}$
Directive D	Mech. dir. coef. MT^{-2}	Hydr. dir. coef. $L^{-4}MT^{-2}$	El. dir. coef. $L^2MT^{-4}I^{-2}$	Prod. dir. coef. $L^2MT^{-2}p^{-2}$	Fin. dir. coef. $L^2MT^{-2}\$^{-2}$
Inertial M	Mech. iner. coef. M	Hydr. iner. coef. $L^{-4}M$	El. iner. coef. $L^2MT^{-2}I^{-2}$	Prod. iner. koef. L^2Mp^{-2}	Fin. iner. koef. $L^2M\$^{-2}$

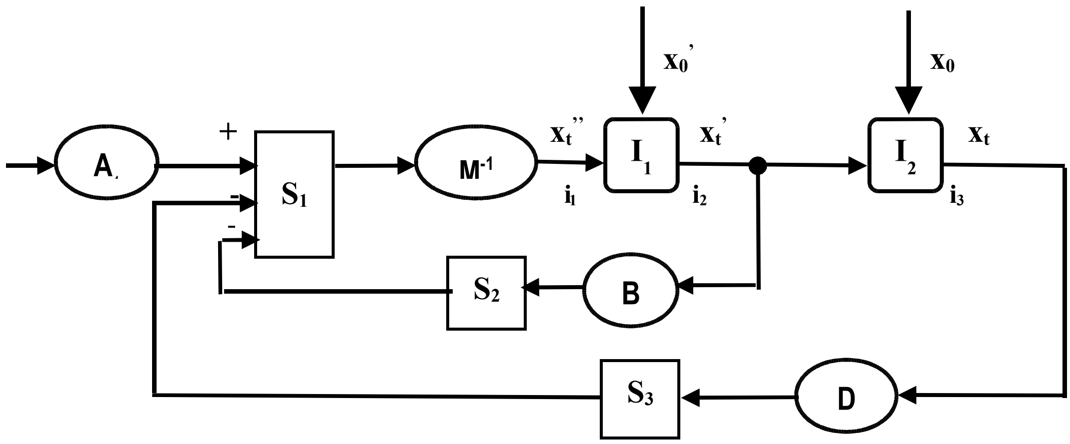
System analogy

When the variables (force-effort-flow) are regarded then the analogy corresponds for the mechanical system (force-deviation-speed), for the hydraulic system (pressure-volume-flow), for the electrical system (voltage-charge-current), for the production system (production force-product-productivity) and for the financial system (financial force-capital-capital flow). Furthermore we can regard the inertial coefficient M, the directive coefficient D and the dissipative coefficient B for the mechanical system M, hydraulic system H, electrical system E, production system P and financial system F.

The first example shows the simple stock market model as a system with feedback. This system can be described by means of the second rate differential equation in the form of

$$M_F\, y''(t) + B_F\, y'(t) + D_F\, y(t) = 0.$$

The following figure shows the implementation of stock market model, where the symbols are as follows: A – input constant, M – inertial constant, D - directive constant, B – dissipative constant, S_1, S_2, S_3 – summation junctions, I_1, I_2 - integrative links.



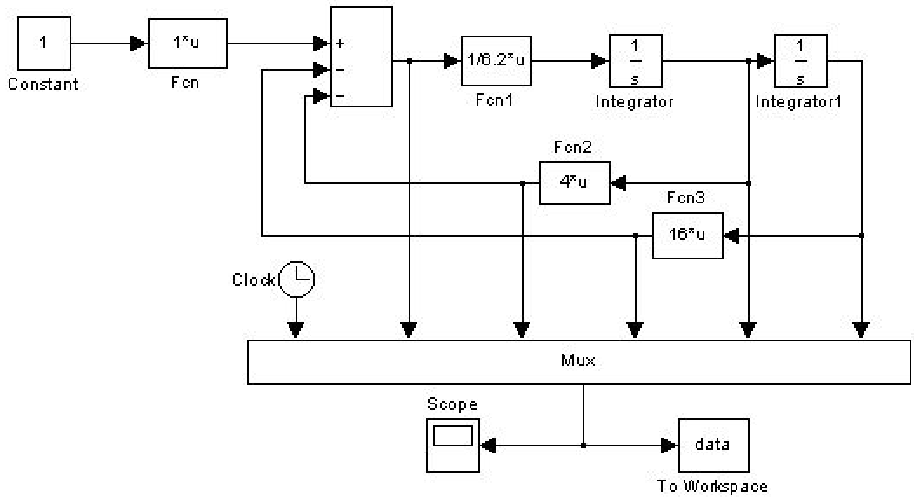
The scheme of model for simulation

The first feedbacks consists of B coefficient and S_2 junction, the second of D coefficient and S_3 junction. The scheme also shows that the junction S_1 calculates the sum of the input value with both feedbacks. The symbol $i_1 = x_t''$ represents the second rate derivation of the variable, i.e. the increase of the capital flow; the symbol $i_2 = x_t'$ represents the first rate deviation of the variable, i.e. the capital flow; and symbol $i_3 = x_t$ represents variable the capital. The symbol x_0' represents the initial condition for the integrative link I_1 and x_0 represents the initial condition for the integrative link I_2.

The following table represents the values of constants and initial conditions and following figure the Simulink scheme

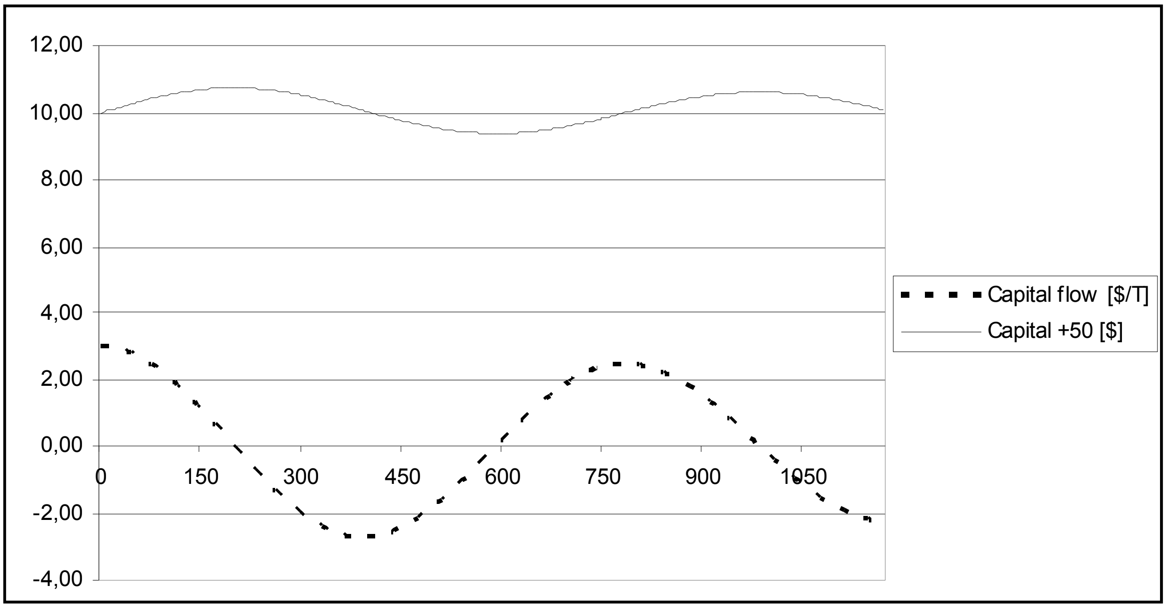
Name	Symbol	Unit	Value
Input constant	A_F	$	1.0
Financial inertial coefficient	M_F	$L^2M\$^{-2}$	2.0
Financial dissipative coefficient	B_F	$L^2MT^{-1}\$^{-2}$	0.5
Financial directive coefficient	D_F	$L^2MT^{-2}\$^{-2}$	32.0
Capital flow (initial condition)	${}_Fx_0'$	$\$T^{-1}$	3.0
Capital (initial condition)	${}_Fx_0$	$	0.0

Table of input values



The Simulink scheme

The following graph is the output showing the courses of i_2 and i_3. Any calculated value can be showed.



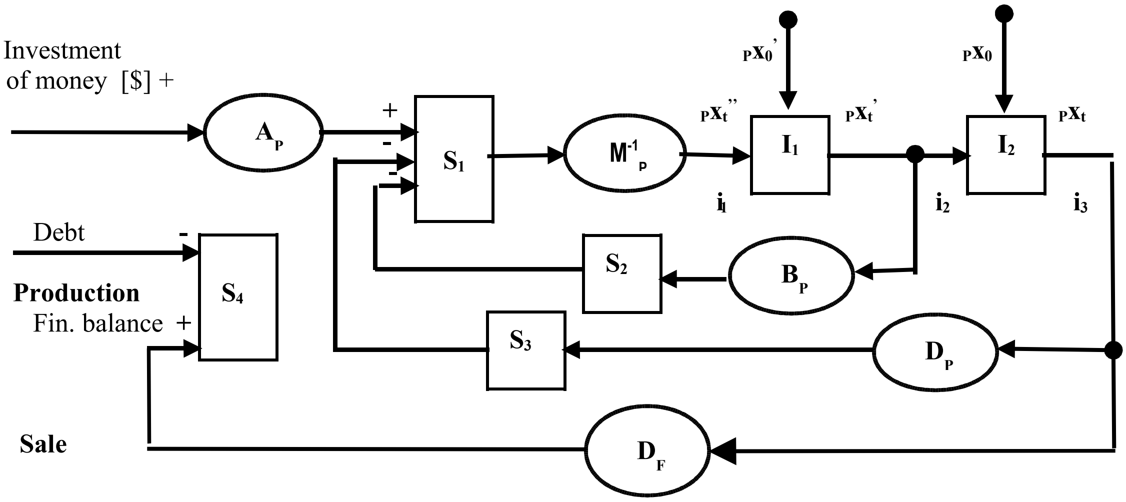
The graph of the output values

The graph displays the curves of the continuing the dynamic process of stock market and investors interactions. The feedback comprising the investors' reactions to the course of the stock market is rather influential in the process. The feedback can be positive or negative. The positive feedback has an amplifying effect, and also a negative influence on the stock market – investor's relation stability. The negative feedback has an attenuating effect and also a positive influence on the stock market – investor's relation stability. A further development on the stock market can be inferred from the graph and new simulations performed to predict the behaviour of the stock market.

The second simple example represents the production workshop model where the production and financial system will be studied. The model has a feedback when we use the differential equations in the form of

$$M_P y''(t) + B_P y'(t) + D_P y(t) = 0 \text{ and } D_F y'(t) = 0.$$

It is necessary to build up the schema of the action in the workshop first before we perform the simulation of these equations. The following figure shows the schema, where index P stands for the production system and index F for the financial system.

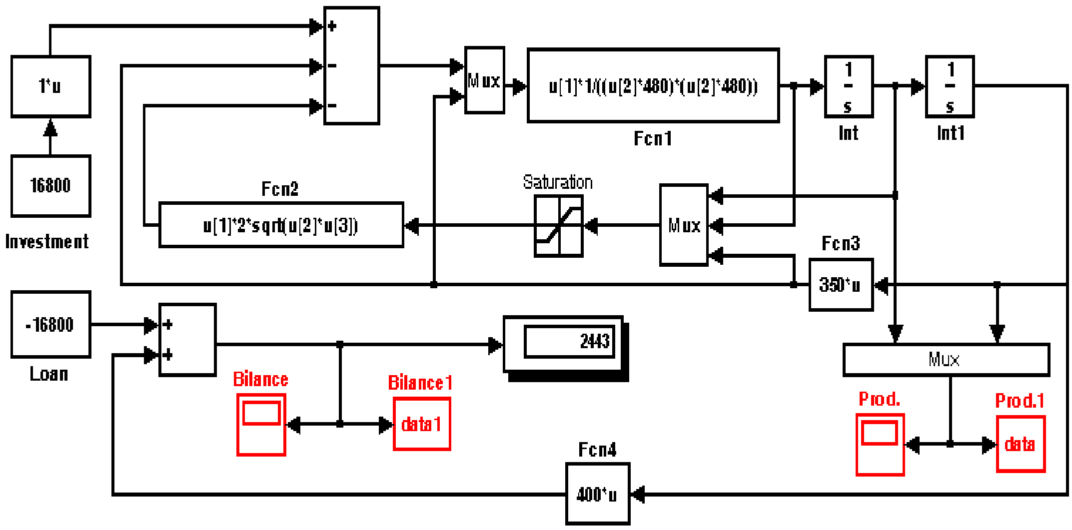


The scheme of model for simulation

The following table represents the values of constants and initial conditions and following figure the Simulink scheme

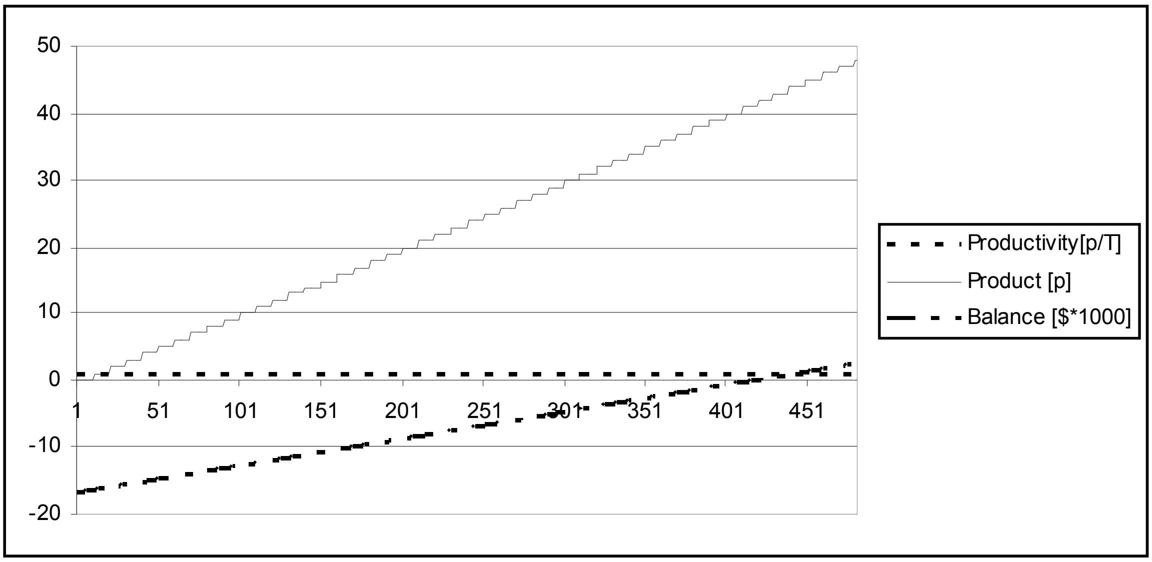
Name	Symbol	Unit	Value
Input constant	A_P	\$	1.0
Production inertial coefficient	M_P	$L^2M\$^{-2}$	$(D_V*T)^2$
Production dissipative coefficient	B_P	$L^2MT^{-1}p^{-2}$	$2*\sqrt{(M_V*D_V)}$
Production directive coefficient	D_P	$L^2MT^{-2}p^{-2}$	350
Financial directive coefficient	D_F	$L^2MT^{-2}\$^{-2}$	400
Productivity (initial condition)	${}_PX_0'$	pT^{-1}	0.1
Product (initial condition)	${}_PX_0$	p	0.05
Time	T	T (min)	480

Table of input values



The Simulink scheme

Graph is the output where $i_2 = {}_Vx_t'$ is the course of the first derivation of a variables, i.e. the productivity, $i_3 = {}_Vx_t$ is the course of the variable in time, i.e. the product. Next e.g. the S_4 junctions (representing balance) can be further studied. These variables are shown on the following figure. Any calculated value can be showed.



The graph of output values

The graph displays the curves of the dynamic process. The process of production starts when money has been invested. The production cycle can be evaluated in a graph where we can study e.g. the courses of variables i_2, i_3 and S_4 junctions. It is interesting to study the S_4 junction where the financial balance is calculated, that is, if and when the production brings profits or losses. The start means investment in production and the end the final profit during one shift. A further development on the stock market can be inferred from the graph and new simulations performed to predict the behaviour of the stock market.

The mentioned case represents the production-financial relations in the workshop. The time period of production of one piece is 10 minutes, i.e. it is produced 6 * 8 = 48 pieces during one 8 hour (480 minute) shift. The cost is 350 $ apiece, therefore it is necessary to invest 48 * 350 = 16800 $ to turn up one shift. It means, that the debt is – 16 800 $. The product is sold 400 $ apiece, it means that the sale is 48 * 400 = 19 200 $. Profit (sale – cost) is 19200 – 16 800 = 2 400 $ within one shift. The graph shows these facts: the productivity is one piece within 10 minutes; the rising number of finished products is from 0 to 48 pieces at the end of the shift (480 minutes); the balance starts with the value -16 800 $ as a debt at the beginning of the shift and results in the value 2 400 $ as a profit at the end of the shift.

The problem is to set the coefficients M, B, D when we calculate the simulation of the production and financial systems. It is not the problem with other systems (e.g. the setting of resistance, capacity, and inductance in electrical system). On the basis of physical systems stating that the oscillatory element is characterized by its own frequency $\omega_0 = \sqrt{(D / M)}$ the functional dependence $M_V = (D_V * T) * (D_V * T)$ and $B_V = 2 * \sqrt{(M_V * D_V)}$ was discovered. See literature 1, 2. The real frequency is influenced by the dissipative parameter B. The actual frequency has to be the highest for the fastest reaction of the system. In this case M must be of the smallest value, D the biggest and B must be of such value to avoid oscillation.

The inertial coefficient of the production and financial systems is influenced by the operating structure, the personality and quality of the boss, workshop relations, and education. The directive coefficient D and the dissipative coefficient B of the production and financial system are influenced by running costs, prices of inputs, wage policy in production, premium and social measures, political influence, etc. The setting of these parameters is very complicated and for their correctness it is necessary to use the active search and estimation of the parameters' values, for example sociological researches.

If we build up the correct description of the production and financial systems we can connect them with other systems. This way it is possible to simulate the energy systems which comprise the mechanical, hydraulic, electrical, thermal, etc. systems and connect them with the production and financial systems. In such systems we can study the influence for example of the change of the electric variables on the financial system and thus dynamically simulate the possible change of the financial balance – profits or losses.

Literature:

[1] Barvíř M.: *Modelování a identifikace,* Brno, Skripta, 1990, 110 s., ISBN 80-214-0302-0

[2] Barvíř M.: *Development of Models of Economical and Ecological Systems,* Zlín, CP&HS 02. Conference, 2002, 6 pp., ISBN 80-7318-074-X.

[3] Dostál P.: *Simulace provozu umělé ledviny na číslicovém počítači,* Praha, Lékař a technika, 1984, Čís. 4, s. 67-75, ISSN 0301-5491.

[4] Dostál P.: *Moderní metody ekonomických analýz,* Zlín, Academia Centrum, FaME UTB, 2002, 110 s, ISBN 80-7318-075-8.

[5] Dostál P.: *Soft Computing and Stock Market.* Brno, Mendel 03, Konference, 2003, 5 s., ISBN 80-214-2411-7

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