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Models for International Stability

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Abstract: Conflict resolution was dominated by more or less verbal approaches some years ago. Nowadays system engineering methods, based on well known principles of control engineering, mathematics, statistics are applied to such problems. One of the main problems arising is the description of the static and dynamic behaviour of conflict partners or systems in form of mathematical methods. Such models are determined either in a theoretical or experimental way. Theoretical model building yields to complicated models difficult to handle. Therefore simple models are mostly used determined in a heuristic way. In the paper methods for model building are presented and as an example a simple linear time invariant model is used to describe gas or oil supply and consumption of several countries.

1. INTRODUCTION

The main idea of SWIIS is to bring together scientists and practical oriented people from different disciplines for discussing different – system theoretical as well as systems engineering - approaches for conflict solution (Chestnut, 1982).

For a long time this field was mainly dominated by scientists from non technical disciplines like political and social sciences. Only few with system-theoretical background tried to develop models for the static and dynamic behaviour of conflict parties or systems. There were two main approaches for model building: Either model based on simple linear differential equations very well known from the classical control theory or computer models based on more or less heuristic time discrete equations.

2. CONTROL (SYSTEMS) ENGINEERING AND CONFLICT SOLUTION

One of the SWIIS approaches is to interprete a conflict situation as a stability problem in one or between more dynamic systems – conflict parties - using similarities between control engineering terms and terms of conflict solution. Therefore in Tab.1 an incomplete listing of such corresponding terms is given. Possible disturbance variables or possible conflict sources are listed in Table 2.

With these corresponding terms conflict situations can be described by various types of dynamic equations, well known from control engineering. Therefore the classical methods from control engineering can be applied.

3. MODELLING TECHNIQUES

There are more or less three possibilities (Kopacek et.al., 1990):The macro economical approach: Types of models are economic relations between various input-, output- and state variables within a nation and/or between nations. These types of variables are usually well known from the literature.

Table 1. Corresponding terms in control engineering and conflict solution (Kopacek et.al, 1990)

Control Engineering	**Conflict solution**
SISO System	Organisation (State) with one goal
MIMO System	Organisation (State) with more goals
Controller	Authority or government
Command variable w	Goal of the authority (government)
Control deviation xd	Execution organ – Goal from the Org.
Controller gain Kp (Xp)	Power of an Organisation (State)
Subsystems	Internal groups or Societies
Disturbance variables z	External: Influences from neighbour systems Internal: Influences from subsystems
Negative feedback	Damping, Stability
Positive feedback	Aggression, Instability
Efficiency	Measure for the ″System Intelligence″
Stability margin	Critical state of the system

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Table 2. Possible disturbance variables (Erbe, Kopacek, 2006)

Geographical: Boarder problems, Invasions
Religious: Prosecution, Discrimination, Conflicts, Fights
Economic: Price limitations, Embargos
Environment: Acid rain, Water pollution
Raw materials: Resources, Prices, Monopoles
Political: Ideologies, Human rights, Minorities
Military: Aggression, Government with no power
Various

The power approach: Basis of these types of models is the compositions of the overall power within a nation and/or between nations into special kind of powers: Economic power, Natural power,

Mental power, individual groups power, Political power…..

The ideological approach: Basis of this philosophical approach is interactions between almost indefinable variables like measures for ideology, society, structure, acceptance, pressure tension, etc.

Usually in practise we have to choose a mixed approach based mainly of one of the three possibilities: ideological approach is very suitable, there are two uncertain definitions, you have a high amount of model parameters to determine and there is a general common nominator. The macro economical approach as well as the power approach leads to results in shorter time.

Macro economic approach is definitely a top down technique. You have to deal with well known economic laws, relations between small sub components the disadvantage is the high amount of model parameters. Bottom up techniques resulted in small overall models but unfortunately information from the complexity of the problem is lost.

Therefore for the task of SWIIS we have to choose mixed technique: first we have to decompose the complex system into simple sub systems which can be mathematically described. That is more or less a top down technique. The next step is the mathematical description of the subsystems in bottom up technique. Finally the sub models resulting complex interactions are combined to the complete model.

4. MODELS

Usually mathematical models have a distinct structure and parameters. While in technical systems the model parameters – the constants in the equations – are well determined by physical laws in non technical systems, like in this case, the model parameters have to be estimated from mostly statistical data.

Dynamic models assume that the whole system may be disaggregated into more subsystems described by simpler dynamic models. There are two principal types of models which are used in systems engineering. Either input-output (external) or stat space (internal) models. While input-output models are suitable for simple linear systems with one input and one output (SISO - Systems), state space models give a deeper insight in the inner relations of a system and therefore they will be commonly used for more complicated systems with multiple inputs and outputs (MIMO-Systems). One specific problem in model building for conflict resolution is how to interpret "measures" and "quantities" (Tab. 1 and Tab. 2) which are necessary to describe the behaviour of conflict partners.

A usual way in systems engineering is to simplify complicated models. In most cases successive simplification finally yields to models of linear time invariant MIMO – systems. The behaviour of such systems might be described e.g. by a set differential equations of first (state space equations) or one differential equation of higher order. By means of these models all well known methods of linear system theory (e.g. controller design, stability theory) can be used.

As an example, in the following the influence of the conflict factor "energy" on stability will be studied by two new model (Erbe, Kopacek, 2006).

5. ENERGY PRODUCTION AND CONSUMPTION IN THE WORLD

The energy prices are currently worldwide near a maximum. The most important driving factors are:

- Instability in Middle East
- OPEC Supply Management
- Shortages of Refining Capacities
- Strong Demand from China

The future demand of energy is directly related to the increasing world population e.g. China, India, South East Asia. There is a clear link between development and energy consumption. The reserves of coal, oil and gas are limited.

Therefore energy saving is currently a hot topic all over the world. For minimising energy consumption we have the possibilities to improve energy efficiency and to improve process efficiency.

These facts underline that energy is and will become one of the most important factors in international stability.

The new approach consists in modelling the energy problem by the classical "Three tank problem" very well known from control engineering.

5.1. Models

5.1.1. Coupled tanks

Fig. 1 shows a very simple model. Tanks represent the storage of gas or oil in a country. The tanks are connected with one pipeline to the supplier.

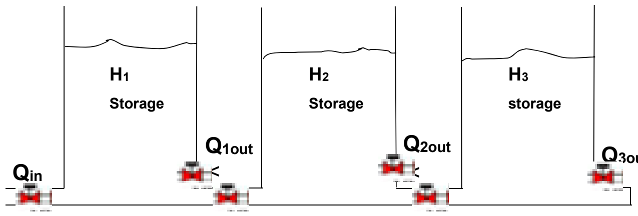

Fig. 1. Coupled tanks.

The tanks have balanced levels with consumptions Q_{out}. Every country has a certain volume H of their tanks (storage) respecting the contract with the supplier. Assume a finite supply per time. Then an over-consumption in one country causes miner consumption in others.

Consider a disturbance of Qin with a step function. To maintain the balance of the levels H it turns out that the configuration of Fig. 1 is unstable.

Dimensions of the filled tanks:
Volume $V_i = A_i * H_i$ [m^3]
connection tubes crossections: a_i [m^2]
The filling levels are

$$H_i = \frac{1}{A_I}\int (Q_{in} - Q_{out})dt$$

The flow between the tanks is

$$Q_{ij} = a_{ij}\sqrt{(2g(H_i - H_j))}$$

Therefore we get three non-linear differential equations for dHi/dt.

The linearized differential equations around the levels H_i (operation point) hold (for $A_i = A$ and

$Q_{in} = K_u * u$, and $H_i = H_{io} + h_i$):

$dh_1/dt = 1/A\ (\ Ku\ u(t) - c_1\ h1(t) - c_2\ h_2(t))$
$dh_2/dt = 1/A\ (c_1\ h_1(t) + (c_2 - c_3)\ h_2(t) - c_4\ h_3(t))$
$dh_3/dt = 1/A\ (c_3\ h_2(t) + (c_4 - c_5)\ h_3(t))$

or as matrix equations:

$$\dot{\underline{h}} = A\underline{h} + \underline{b}u$$
$$\underline{y} = C\underline{h}$$

c_i are constants depending on H_{io}, $a_{i,j}$, and g.
A has the components:

$a_{11} = -c1$, $a_{12} = -c2$, $a_{13} = 0$;
$a_{21} = c1$, $a_{22} = c2-c3$, $a_{23} = -c4$;
$a_{31} = 0$, $a_{32} = c3$, $a_{33} = c4-c5$.
$\underline{b}^T = 1/A\ [Ku\ \ 0\ \ 0]$,
C = [1 0 0
0 1 0
0 0 1]

Fig. 2 shows the calculated $h_i(t)$ for H_{i0} = 25 [m] with MATLAB.

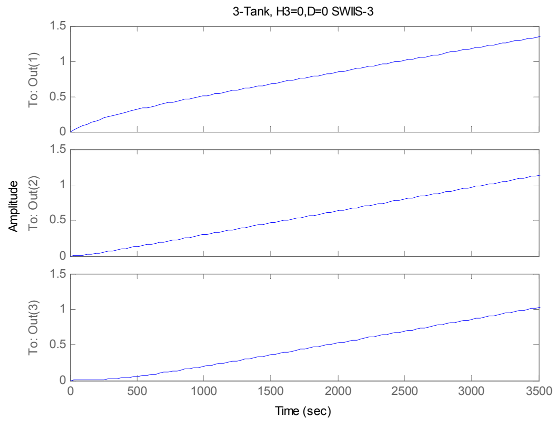

Fig. 2. $h_i(t)$ [m] for A = 1000 [m^2], $a_{1,2} = a_{2,3} = 1$[m^2], $a_{3,0} = 0$.

Fig. 2 shows the instability. Solving this problem one could try to control the level of one of the tanks – tank 3.

$h_3(t) = f_1(\mathbf{A}, \underline{b}, Kp)$
$h_2(t) = f_2(h_3(t))$
$h_1(t) = f_3(h_3(t))$

Fig. 3 shows the result if tank 3 is proportional controlled (by negotiaton with the supplier). The other tanks are of course affected. The result in Fig. 3 was obtained with a gain Kp = 4. Kp > 4 causes instability in all tanks.

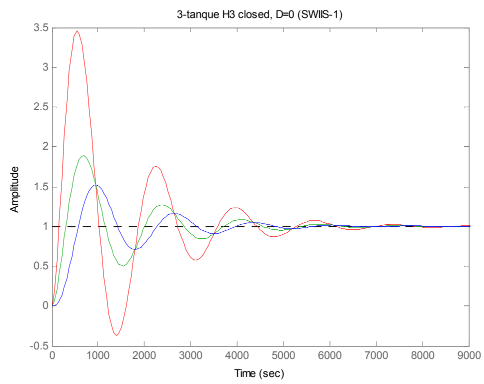

Fig. 3. $h_i(t)$ if tank 3 is P-controlled with Kp = 4.

Consider now a full state feedback control. The result of the calculated values of the feedback vector $\underline{k}$ (depending of the chosen poles) shows Fig. 4.

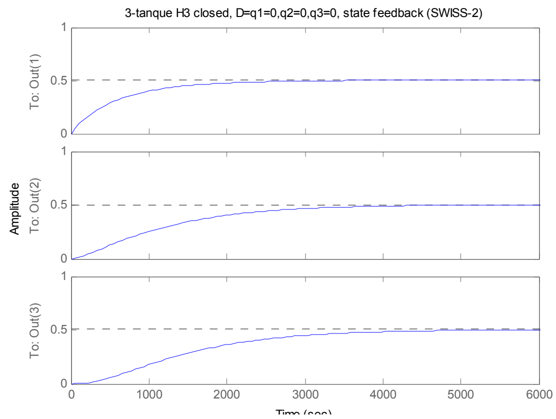

Fig. 4. $\underline{k}^T$ = [0.1780   0.0090   1.7926]

The system matrix A changes to A_k = A-$\underline{b}$*$\underline{k}^T$. That means a controlled outflow c_z =1.8 of tank 1 as a function of the level H3 stabilizes the system   (Fig. 5).

A-$\underline{b}$*$\underline{k}^T$ = [-0.0033   0.0031   -0.0018
0.0031   -0.0063   0.0031
0   0.0031   -0.0031]

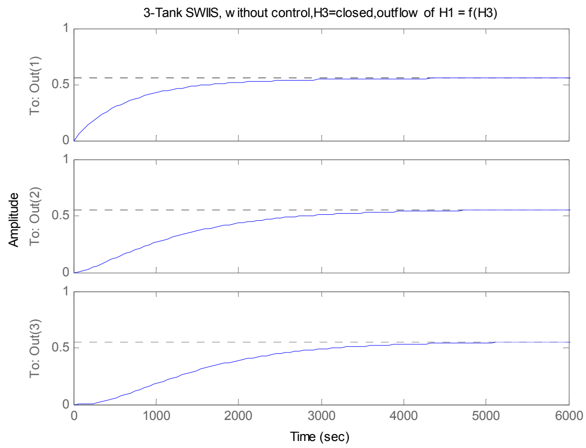

Fig. 5. Stabilized tanks against disturbances with a controlled outflow of tank 1 as a function of H3.

5.1.2. Full state feedback control of MIMO-systems

Because of the un-sufficient results another model and an "advanced" control concept is used.

The variation of the levels of the tanks described by

$$\dot{\underline{h}} = A\underline{h} + B\underline{u}$$
$$\underline{y} = C\underline{h}$$

$$A = \begin{pmatrix} -(a_1+d) & a_2 b \\ a_1 & -a_2(b+g) \end{pmatrix}, B = \begin{pmatrix} Zv_1 & 0 \\ 0 & Zv_2 \end{pmatrix}$$

with Zv1=1; Zv2=1; a1=0.05; a2=0.05; b=0.1; d=0.1; g=0.1; and a step input is shown in Fig. 6.

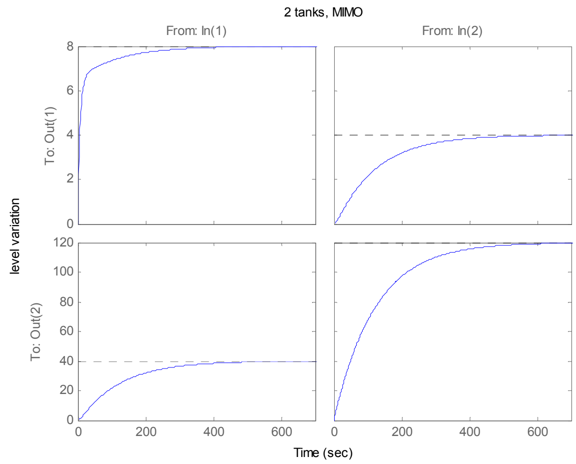

Fig. 6. Level variation of the tanks without control

Consider now a full state feedback (Fig. 7). The control law is

$$\underline{u}(t) = -R\underline{h}(t) + V\underline{w}(t)$$

with a constant control matrix R of constant elements and a pre-filter matrix V also of constant elements.

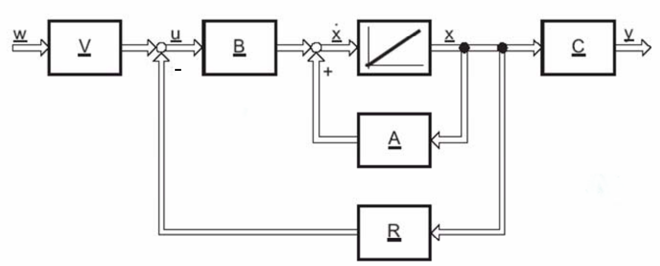

Fig. 7. Full state feedback

The governing equation is given by

$$\dot{\underline{h}}(t) = (A - BR)\underline{h}(t) + BV\underline{w}(t)$$
$$\underline{y}(t) = C\underline{h}(t)$$

Using Laplace Transform

$$\underline{y}(s) = C(sI - A + BR)^{-1} BV\underline{w}(s)$$

This allows the calculation of the pre-filter matrix V. For steady state conditions (s=0) should y(s) = w(s). V has not been calculated here. The control matrix R can be chosen to influence the systems stability or other performances. MATLAB allows the numerical calculation for given poles. Fig. 8 shows the result for poles p1= -0.15; p2 = -0.1.

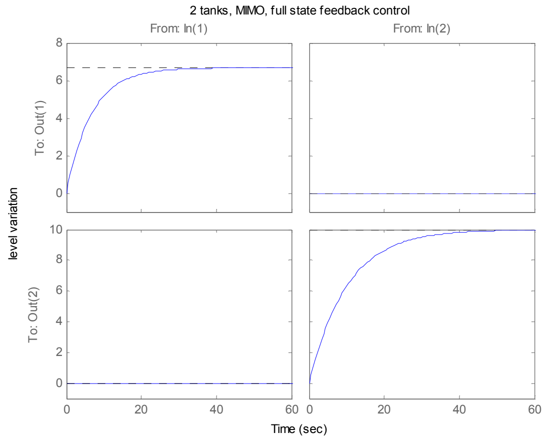

Fig. 8. Full state feedback, p1=-0.15, p2=-0.1

Because only the vector h has been used for feedback input u_1 does not affect output y_2, and u_2 does not affect y_1.

This changes if output feedback is used (Fig. 9).

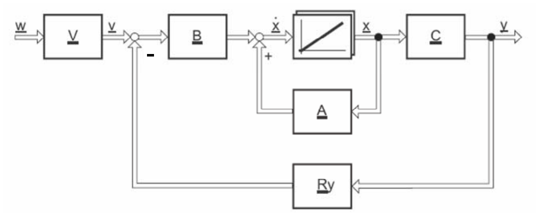

Fig. 9. Output feedback

$$\underline{u}(t) = -R\underline{y}(t) + V\underline{w}(t)$$

$$\dot{\underline{h}}(t) = (A - BRC)\underline{h}(t) + BV\underline{w}(t)$$
$$\underline{y}(t) = C\underline{h}(t)$$

Without calculating the pre-filter matrix V, and

$$R = \begin{pmatrix} 2 & 1 \\ 1 & 2 \end{pmatrix},$$

the simulation with MATLAB using a step function is shown in Fig. 10.

5.2. Discussion

The simple models and calculations do not claim to completely explain the effects of energy supply and consumption. But it could foster an understanding of possible instabilities when trying to control supplies separately and not in the context of the network.

The model of section 5.1.1 is not very realistic for networks of supplying. However, this model explains why and when unexpected instabilities occur. The model described in section 5.1.2 is more realistic because this is based on MIMO systems used for designing networks of electrical energy supply. Last time one could get aware of problems that have caused blackouts in electrical energy supply.

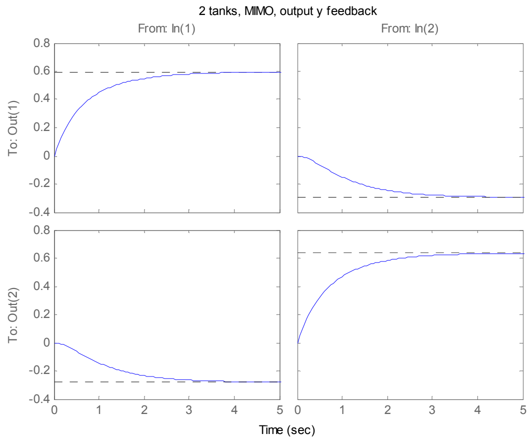

Fig. 10. Tank level variation with output feedback

Full state feedback control may be sometimes unrealistic for solving practical problems. The introduction of observers can be helpful. There are much more complex models for such subjects available in the literature. Examples are models for nonlinear, time varying or stochastic systems. According to our experiences these models yield to more realistic results but the computing power increases dramatically. Another problem is the determination of the model parameters usually from historical data. These are only available in few cases.

6. CONCLUSION

The intention of this contribution is to present some models and modelling techniques well known from control engineering. For application to conflict solution there are special problems. As an example a simple model for energy supply and consumption between countries and the control is presented and discussed.

7. REFERENCES

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