INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKHOLM, AUGUST 19-21, 2003

IDENTIFICATION OF A CRITICAL LEVEL OF COOPERATION IN A COOPERATIVE – COMPETITIVE RELATIONSHIP

Lovén Eva and Krus Petter

Abstract

In this paper three different types of a cooperative-competitive relationship in engineering are presented. These critical relationships were identified in three different empirical studies and a mathematical model to describe these dynamics of cooperation and competition has been developed. The conclusion is that there is a critical level of coopetition where the cooperative relation breaks down, and a very small perturburation can plunge a successful case of coopetition, that is beneficial for both, into pure competition.

Keywords: Critical level, cooperation, coopetition, modelling, engineering design

1. Introduction

Products have become more complex and therefore engineering design and product development work must relay more on collaboration between individuals, teams and companies for the product realisation [1], [2]. But collaboration implies both cooperation and competition and in most cases the situation can be described as something in between pure cooperation and pure competition and, hence, it is important to understand the dynamics of this phenomena.

Co-opetition is a word used to illustrate the dilemma to compete and cooperate at the same time, see for example Dawling et. al [3]. On an organizational level they could see multifaceted relationship, when a supplier, buyer and/or partner is also a major competitor. According to them having a competitor, as a partner can be risky and companies in multifaceted relationships experience role conflict. Under co-opetition there is a paradox that the knowledge shared for cooperation may also be used for competition [4]. Kohn [5] studied more closely what competition and co-operation does to us on an individual level. For example the higher the concentration of competition in any interaction, the less likely it is to be enjoyable and the more likely it is to be destructive to our self-esteem, our relationships, our standards of fairness.

Even if the problem - to compete and cooperate at the same time - is known in general terms, there is little research how to model and manage the problem in engineering. Some exceptions on modelling are Loebbecke et. al., [4] Meyer [6] and Starkermann [7]. One of the manager's roles is to understand the benefits of cooperation and the losses from competition between people and between groups [8].

The aim with this paper is the dynamics of co-opetion in a cooperative and competitive engineering design context. The focus in this paper is both on a company and individual level.

2. Method

In the purpose to identify the critical level of cooperation in a cooperative and competitive engineering context the research began to identify different types of cooperative-competitive relationship in three empirical studies concerning engineering design [9], [10], [11]. In total 38 in–depth interviews were performed.

Table 1. Number of people interviewed

	Number of people interviewed
Study I [9]	Eight engineers (integrators and consultants) and two managers
Study II [10]	12 managers in the area integrated hard- and software
Study III [11]	18 managers in the area of information technology, R&D and production

The second step in this research was to develop a simulation model. The inspiration to the simulation model came from results from the three studies. The simulation model is based on a few basic assumptions. In a relationship of coopetition the contribution for both parts are combined to form the value (result). The value may, however, be a non-linear function of the two contributions. The value is then shared using another non-linear function, defining the level of competition. The result is fed back to the actors and is allowed to affect their performance.

The simulation is done in the HOPSAN simulation package developed at the Department of Mechanical Engineering at Linköping University, Sweden.

3. Results

3.1 Results from the three empirical studies - different types of cooperative-competitive relationship

The three empirical studies showed three different types of cooperative and competitive relationship when engineering became critical namely hiring consultants on an individual level (study I) the traditional mechanical company working with software partners (study II) and working with innovations on a company level (study III), see table below.

Study I [9]
The aim of the project was that the consultants would create the models from the written documents generated by the system engineers, i. e. the integrators. Most of the system-engineers, with responsibility for the system requirements, stated that they wanted more time to work with the tool and the model. In this way the knowledge of model generation with this tool stays within the company. However, that was not their task: it was the task of the consultants to create the model. The consultant created the models and worked not as a trainer.

Table 2. The empirical base

	Type of engineering design work	The cooperative and competitive relationship	The critical situation
Study I [9]	Modelling and simulation work with computer based tools for complex hybrid systems	Systems engineers and the software consultant	The consultant created the models and worked not as an trainer
Study II [10]	Integrating software to traditional mechanical products	The traditional mechanical company working with software partners	Some of the cooperation with partners had not gone well, difficulties with trust
Study III [11]	Product development work and innovation	Product development together with suppliers and/ or consultants but innovation were done by their own	Product development harmless work but the more innovative product, difficulties with trust and who are you challenge?

Study II [10]

Another case of coopetition is the relationship between a company and its subcontractors. Management in the traditional mechanical company (one of the early explorer companies) had difficulties to find external partners with software experience. They needed these partners to develop integrated hard- and software products. When they found the partner they had difficulties with cooperation and trust. The partner found was working with competitors.

Study III [11]

The third study showed that product development is often carried through together with suppliers and/or consultants however this was not the case for innovations. The following quotation shows this.

“Together with consultants we conduct product development, but innovations we do by our own. I am speaking about real new thinking this is something you can’t outsource.”

In this company the respondents expressed that circulating ideas for comments are a great danger, experts will be challenged and the idea killed. The following statement expresses different aspects of obstacles in the development process.

“ … To see combinations of different technologies is difficult. You must ask who we challenge? There could exist a GURU who felt threatened. An unaccompanied cannot change the established work process. You must be a group or be outside…You must have the insight on a system level.”

In the three studies above all represents different types of critical cooperative-competitive situations. These are characterised by a potential for mutual benefit, offset by a risk for breakdown into a “winner takes it all” competitive situation. In the next section the mechanism is described in mathematical terms and simulated.

3.2 Mathematical modelling and simulation

Since underlying phenomena in these studies seems to be a case of a blend of cooperation and competition, and a shifting balance between the two extremes, it should be possible to make some mathematical models that at least quantitatively can capture the phenomena. The two groups (individuals) struggling for the same aim (i.e. to learn new computer-based tool and to be productive with them) but they have slight different abilities (or the tools have slightly different abilities).

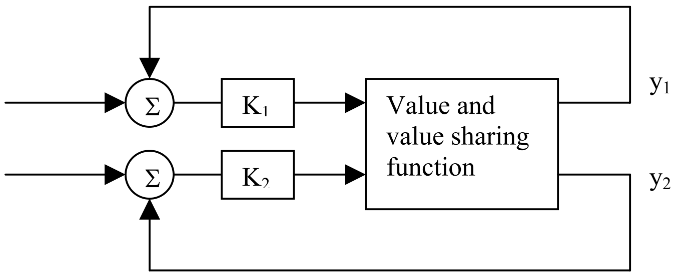

Figure 1. Basic feedback system of two co-opetive partners

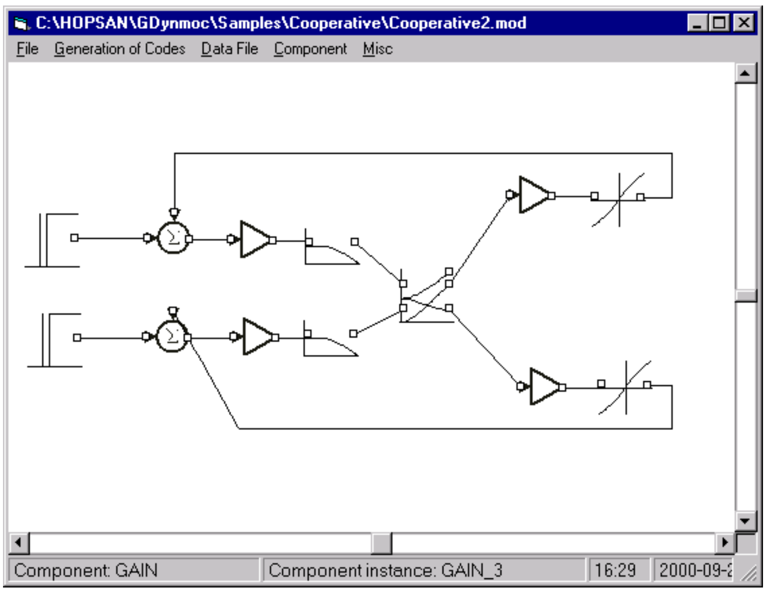

Figure 2. The simulation model.

The inputs to the left represent the amount of effort that each part is putting into the system per time unit. In the example shown here the value 1 (i.e. full time). Each of these signals are then added to a feedback value and fed through gains representing their productivity. The upper one of these has gain k=1 while the other have k=0.9 meaning that the performance of the second group (or individual) is slightly inferior.

The signals are then fed through low-pass filter that serves as delays and smoothening of the productivity values. This represents the fact that there is a delay between an effort and the time when the result obtained and evaluated.

Both signals are then fed into an evaluation function that calculates the combined utility value of the combined efforts and produce a value corresponding to the credit of each contributor.

The credit values are then fed through gains with k=1. (They do not affect the result in this example but they provide an additional degree of freedom for further experimentation). The resulting values are then fed through sigmoid function that acts as soft limits to the signals. The result is the fed-back to the respective inputs. The limitation is used to represent the fact that there is an upper limit to work performance regardless of the level of reward (at least on a individual basis). The feedback can correspond to any kind of reward as a result of work performance either in resources (more time allocation or more money) or just joy and inspiration. Using this model it is possible to study the dynamics of the interaction between the two individuals/groups.

3.2.1 The functions used in the simulation model

The low pass filter is defined as

$$G_f(s) = \frac{1}{\frac{s}{\omega_0} + 1} \text{ where } \omega_0 = 10$$

3.2.2 The utility value function

The utility value function is defined as

$$y = (u_1^\gamma + u_2^\gamma)^{1/\gamma}$$

This function has the characteristic that y is larger than the sum of u1 and u2 when γ is less than one, and less than the sum if γ is greater than one.

The individual result are calculated as

$$y_1 = \alpha(u_1^\gamma + u_2^\gamma)^{1/\gamma}$$

$$y_2 = (1-\alpha)(u_1^\gamma + u_2^\gamma)^{1/\gamma}$$

These are used for feedback. α is a factor calculated as

$$\alpha = \frac{u_1^\gamma}{|u_1|^\gamma + |u_2|^\gamma + \varepsilon}$$

(ε is a small positive value to prevent division with zero)
This represents the relative contribution of the individual with index 1.

Neutral competitive- co-opetition
If y2=1, γ=1 and y1 is varied the graph in figure 3 is obtained. This means that the results can be added straightforwardly (two persons producing units instead of one). In this case it is also straightforward to share the profit. It is directly proportional to the number of units produced.
In this case the utility value of the combined inputs is simply the sum of the inputs and the results can be added straightforwardly (two persons producing units instead of one).

Furthermore, the credit value, for each input is simply proportional to the amount of effort inserted. This corresponds to a neutral co-opetive context (or simply neutral). Both inputs are combined for a utility value but each individual/group does not benefit, or lose, from the result of the other individual/group

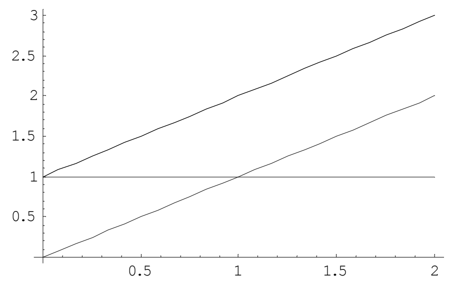

Figure 3. Neutral competitive- co-opetition

Competitive- co-opetition
If the parameter γ is changed to $\gamma=2$ the graph below is obtained.

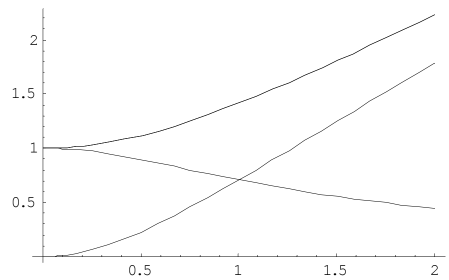

Figure 4. Competitive- co-opetition

In this case the combined utility value is less than the sum of the inputs. This could be the case if a considerable effort is needed in order to be able to combine the result, such as overhead required to coordinate people.

In this case the credit, to each individual input, takes another form. One reasonable assumption is that if one input is dominant it should take most of the credit for the result. The value α is used here to distribute the credit between the two inputs. With the definition used here, which of course is somewhat arbitrary but not at all unreasonable. The credit for u1 is declining as u2 is increasing. This does reflect the fact the input u1 has a diminishing influence on the total utility value.

This is a competitive- co-opetive context (henceforth competitive). Both inputs are combined for a utility value but each individual/group have a negative benefit from the result of the other individual/group.

Cooperative-co-opetition
If the parameter γ is changed to γ =0.5 the graph below is obtained.

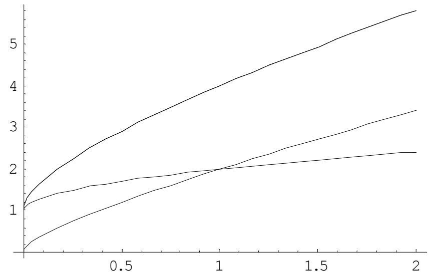

Figure 5. Cooperative-co-opetition

In this case the combined utility value more than the sum of the inputs. This could be the case if considerable synergetic effects are obtained when the results are combined, i.e. then individuals/groups with complementary capabilities cooperate. The credit for u1 is here increasing as u2 is increasing.

This is a co-operative-co-opetive context (henceforth co-operative). Both inputs are combined for a utility value and each individual/group have a positive benefit from the result of the other individual/group. Of these cases both the co-operative-co-opetive and the neutral-opetive are fairly predictable and straightforward. The positive feedback will yield an improved performance in both groups (individuals). The more interesting case is the competitive-co-operative case.

Using a value of γ =1.8 yields an behaviour where both groups (individuals) are improved. This is shown in Fig 6. This represents a sub-critical competitive context.

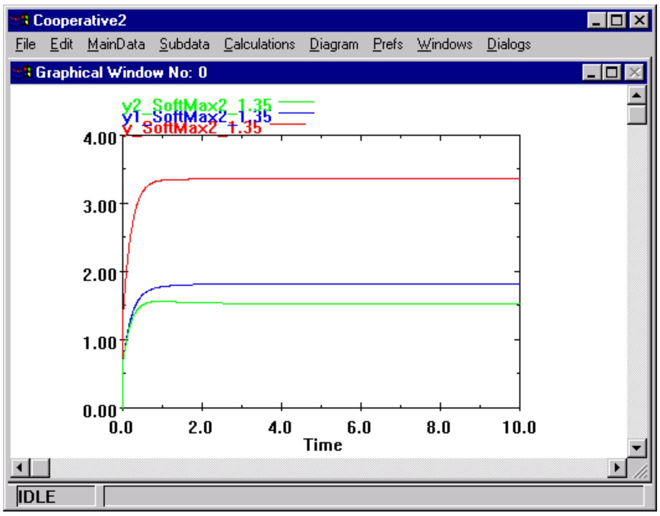

Figure 6. A sub-critical competitive context. Both groups (individuals) improved.

Figure 7 shows the case where γ =2.2 this represents an over critical competitive context improved only one of the groups (individuals). The “winner” takes it all.

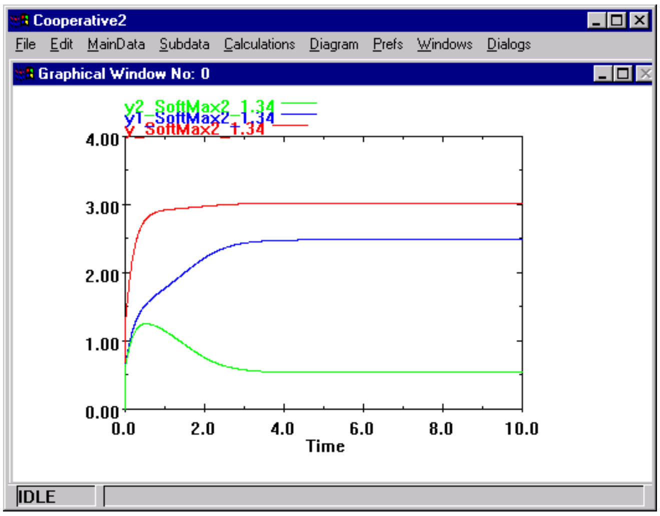

Figure 7. A competitive context. Only one of the groups (individuals) improved the other collapse, resulting in a lower total output.

The simulation results show a discontinuity in the relationship of two actors. At a certain point between cooperation and competition the relationship make a jump and one of the actors collapse. This indicates that there is a critical level of coopetition where a small perturbation can make the system turn into a pure system of competition.

4. Discussion

As we mentioned in the introduction the problem - to compete and cooperate at the same time - is known in general terms. For example Cherns [12] found that hiring specialists adds to the problems of organizational integration in many ways and the expert as a trainer serves the organization quite differently. This were illustrated in our study I. A related concept to study III is “creative destruction” [13] and so on. The different types of critical situations as such are not the new in our study. The main contribution is that we have further simulated the three different situations and shown how this criticality can be understood in mathematical terms. Of course one can be critical to simulations models, but the main point here is not the quantitative aspect, but rather that the fact that the existence of this break down can be shown.
.

The mathematical modelling and simulation above (figure 7) shows clearly an undesirable situation. The “winner” takes it all. It can, however, be resolved by introducing compensations in the feedback by the management, thus effectively transforming a potentially competitive situation into a co-operative one. This shows the importance of proper management in highly competitive environments.

The simulation models simplify the real situation, and as always you have to be careful selecting the correct in-data.

5. Conclusions

The conclusion, from both empirical and theoretical studies, is that there is a critical level of coopetition where the cooperative relation breaks down, and a very small perturbation can plunge a successful case of coopetition, that is beneficial for both, into pure competition. Mathematical modelling has been used here for explaining this behaviour.

Two kinds of competitive system were identified; under-critical and over-critical, where the over-critical competitive system is destructive in the sense that it leads to collapse of some of the participants. The behaviour of the mathematical model corresponds to the concern experienced when collaborations are to be initiated, where the risk of being subjected to a competitive situation is weighted against the potential benefits of a successful cooperation.

The paper shows that modelling and simulation can be a potential tool for understanding collaboration relationship in design but also to assessing arrangements of collaboration at the early stage in the process of forming a design team.

Future research can test the models on real situations and find out whether simulations could be used to signal the need for change in the dynamics of cooperative/competitive relationship.

References

[1] Beskow, C., 2000. Towards a higher efficiency: Studies of changes in industrial product development. Doctoral Thesis. Royal Institute of Technology, Stockholm. TRITA-MMK 2000:7.

[2] Nittmar, H., 2000. Produktutveckling i samarbete. Stockholm School of Economic, EFI, The Economic Research Institute, Stockholm (in Swedish).

[3] Dowling, M. J., Roering, W. D., Carlin, B. A., Wisnieski, J., 1996. Multifaceted relationships under coopetition. Description and theory. Journal of Management Inquiry, Vol.5 No.2, June, 155 – 167.

[4] Loebbecke, C., van Fenema, P. C. and Powell, P., 1998. Knowledge transfer under coopetition. In proceedings Information Systems: Current issues and future changes. Helsinki, Finland. Dec 10-13.

[5] Kohn, A., 1986. No contest. The case against competition. Why we lose in our race to win. Houghton Mifflin Company, Boston.

[6] Meyer, M. A., 1995. Cooperation and competition in organizations: A dynamic perspective. European Economic Review. 39. 709 - 722.

[7] Starkermann, 1988. The attractiveness of aggression –die attratktivitaet der aggrassion. Proceedings of the IASTED International Symposium Modelling, Identification and Control, Grindwald, Switserland, February 17-19.

[8] Deming, W. E., 1994. The new economics. Second Edition. MIT CAES. Cambridge.

[9] Lovén, E., 1999. Modeling and computer-based tools for complex hybrid systems – organizational and human aspects. In Planned Change and Inertia – Integrating Technology, Organization and Human Aspects. Linköping Studies in Science and Technology. Dissertations No. 562.

[10] Karlsson, C. and Lovén, E., 2002. Developing complex products: Integrating software in manufactured products. Proceedings of the 9th International Product Development Management Conference. Sophia Antipolis, France. May 27-28.

[11] Lovén, E. and Karlsson, C., Systems of Innovation from a Management Point of View – Information Technology in Manufacturing Companies. Proceedings of the 11th International Conference on Management of Technology. Miami USA. March 10-14.

[12] Chern, A. 1987. Principles of sociotechnical design revisted. Human Relations, 40, 153-163.

[13] Dahmén, E., 1942. Economic-Structural Analysis. Reflections on the problem of economic development and business cycle fluctuations. In Carlsson B. and Henriksson, R. G. H., 1991. Development blocks and industrial transformation. The Industrial Institute for Economic and Social Research.

For more information please contact:

Eva Lovén, Linköping University, Department of Mechanical Engineering, SE-581 83 Linköping, Sweden
Tel: + 46 13 281661 Fax: +46 13 282579 E-mail:evalo@ikp.liu.se

Petter Krus, Linköping University, Department of Mechanical Engineering, SE-581 83 Linköping, Sweden
Tel: + 46 13 281792 E-mail:petkr@ikp.liu.se