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EMPOWERING SYNERGY DYNAMICS IN CHAOS CONTROL IN HIERARCHICAL TEAMWORK

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Abstract: *In the present paper the methodology of a probabilistic prognosis of the time needed for the design and commissioning of new automated factories is presented. The methodology is based on empirical research of the statistics of human shortcomings collected by the first author from the experience of the start-up of 26 different factories all over the world. It is shown that human shortcomings in hierarchical teamwork lead to a real chaos, which must be taken under control by temporary mapping and well-timed dynamic empowering the synergy level by reasonable rework and tune-in. The practical use of this methodology has proved that losses of labour costs caused by human shortcomings can be cut by up significantly.*

Key words: factory automation, teamwork management, chaos control, synergy deployment, design structure matrix technology, discrete event modelling.

1. INTRODUCTION

One of the key problems at planning the necessary financial recourses for a new automated factory project is the determination of the time for its design and commissioning. At first sight, it seems to be a comparatively simple task. However, in reality it turns out to be a very complex budgetary headache due to human shortcomings (faults, mistakes and strategic miscalculations), which are an inseparable part of human activities in their professional work [1]. Experiences of starting up new automated factories have shown that in order to reach the stage of normal production extra resources of 5-10% of total labour costs on average are necessary. It is a good ground for researching this phenomenon and finding ways to cut down these excessive costs.

The authors of the present paper have been studying the phenomenon of the so-called “bad” engineering for over 20 years with the aim avoiding it by increasing synergy in cooperating teamwork [2]. The latest research has been devoted to synergy-based chaos control in complex hierarchical teamwork similar to the realization of factory process control systems’ projects [3].

The automated factory design and commissioning team is a typical hierarchical system structure of working groups. Such a multi-agent dynamic distributed intelligence system, where the information about the completed tasks is transferred in scheduled time from one team to another, is highly sensitive to tainted information [4, 5]. Imperfect information flow leads to poor decisions and chaotic decision-making by downward agents leading to chaotic behaviour in the whole automated factory design and commissioning teamwork. Taking into account that human shortcomings have an accidental nature it makes chaos control an extremely complicated and nonlinear task, which cannot be solved by classical methods [4, 6].

To overcome the above described situation a two-level approach was outlined. On the first level [3] an exhaustive synergistic information transfer system was created with the aim of suppressing the growth of chaos from the very beginning. For this purpose the most suitable tool was found to be the Design Structure Matrix (DSM) technology. DSM is a powerful tool for describing human relations, making up the most capable teams and scheduling and evaluating their activities [7, 8]. All this allows creating an optimal communication and cooperation scheme between individuals and project groups, where the competences and capabilities of team members can be made maximal use of in the synergy growing manner. In the present follow-up paper to the [3] the second level activities of chaos control in automated factory design and commissioning process are presented. The goal of the second level tasks is to work out a methodology for probabilistic estimation of the automated factory project time.

2. OUTLINING THE RESEARCH PLAN

The present follow-up research is focussed on the aspects of optimal timing control in the automated factory design and commissioning project teamwork. The special feature of this research is the reality that all time-dependent input parameters related to human shortcomings are fully accidental. Therefore, it is possible to rely only on soft computing solutions [9]. As a result, one can see that the estimated project duration consists of statistically determined average time corrected with on-line activities to reduce this sight duration. To attain such a timing ability it is necessary to develop the inhibitive chaos control system by temporal mapping of the situation and by well-timed dynamic correction of the synergy level by reasonable rework and tune-in. The key problem here is reasonable mapping of the growing chaos and correction of the chaotic trajectories to suppress the chaos by empowering the synergy in teamwork.

For the present research a unique advanced database of human shortcomings was completed by the first author on the basis of the experiences gained during the start-up process of 26 different factories all over the world [3]. As a result, factual statistical data about human shortcomings can be used as inputs and the results of the theoretical research can be verified with reality.

Now it is appropriate to point out the use of the concept of synergy dynamics in the present research. In the present situation the synergistic approach is applied to a larger hierarchical socio-technical teamwork system. Therefore, it is substantial to focus on the quality of cooperation and information transfer.

In this context the quantitative evaluation of synergy moves to the foreground. The most appropriate way to comprehend the essence of synergy seems to be the use of a percentage scale (Fig. 1), where 0 represents a synergy-free system or a system completed without any intent to incline from the formal fitness demands and 100% means reaching maximum synergy, where everything is squeezed out of physical, communication and cooperation processes.

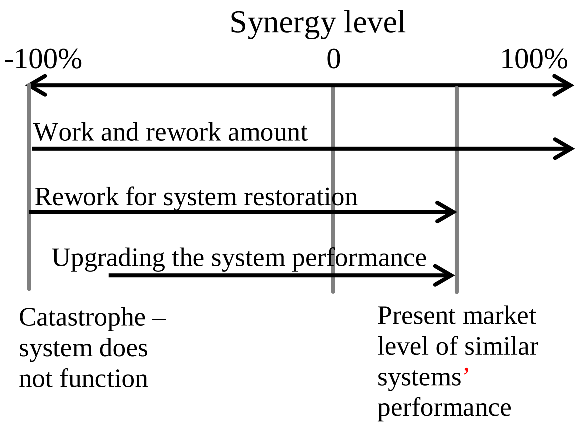

Fig. 1. Relation of positive and negative synergy to rework amount.

Negative synergy -100% marks a catastrophe situation, where the whole process is failed and further activities of restoration must be provided. The level of synergy must be maximally close to market demands for ordinary products including factory process control systems. In principle, the growth of synergy can also be measured by rework time put into the empowering the synergy (see Fig. 1).

Although the framework for describing communication activities is DSM, the most suitable mathematical tools for the analysis of time-dependent processes appears to be an advanced simulation technique – Discrete Event Modelling enriched with Latin Hypercube Sampling [10]. This type of modelling makes it possible to find the best communication map to minimise the time for rework and iterations during project execution.

3. GROWTH OF THE HIERARCHIC CHAOS AND ITS MAPPING

The fundamental basis for the development of any new chaos control approach is a full description of all the inputs, agents, their activities and interfaces between them during the whole automated factory design and commissioning process (see Fig. 2).

This scheme consists of teams formed by commercial sub-projects, tied with financial agreements and bound together by the owner's team's activities.

Effective execution of project tasks by team members requires the planning of information flow between team members and different companies involved. The scheduling of teamwork is supervised by the project manager and team leaders. However, a lot of direct communication also occurs between team members, but their schedule is somewhat random and not fully controlled. The initiator of information exchange is usually the team member who needs certain input to perform a specific task.

The visualisation of a communication pattern of an example project organisation is given in Fig. 3. All the communications between the team members are represented by different colours of arrows, where violet arrows stand for moderate interaction and res arrows strong interaction. The direction of the arrow represents the initiator of communication. Communication can also be bidirectional by means of mutual discussions and meetings.

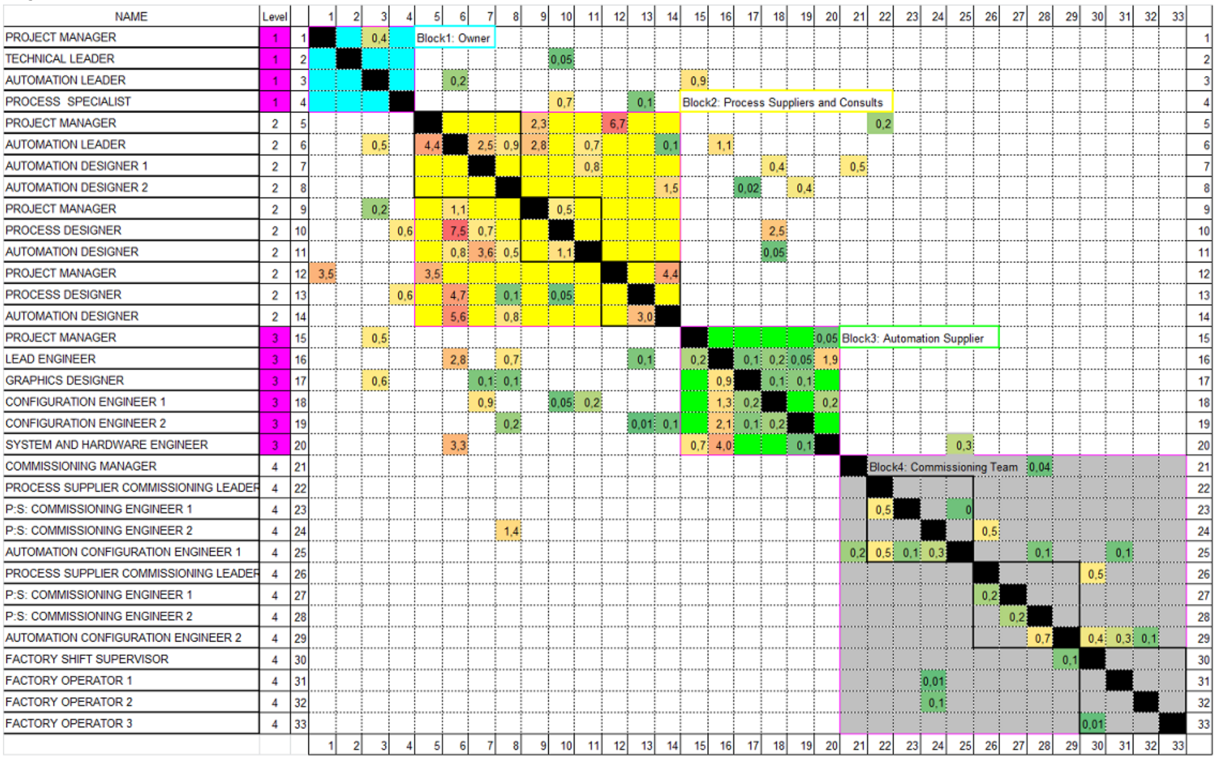

Fig. 2 Typical factory process automation team organisation scheme and shortcomings map in DSM matrix form

Taking into account everything mentioned above one can see that human shortcomings in the form of faults, mistakes or strategic miscalculations, which spread in any of arrow lines in Fig. 3 and multiply at every summing agent in the form of a wrong decision, cause a real chaos in the whole hierarchical system. As the formation of human faults and mistakes is fully accidental and therefore project activities are also somehow chaotic, an indisputable need arises to get control over the whole process and decompose this puzzle in some way.

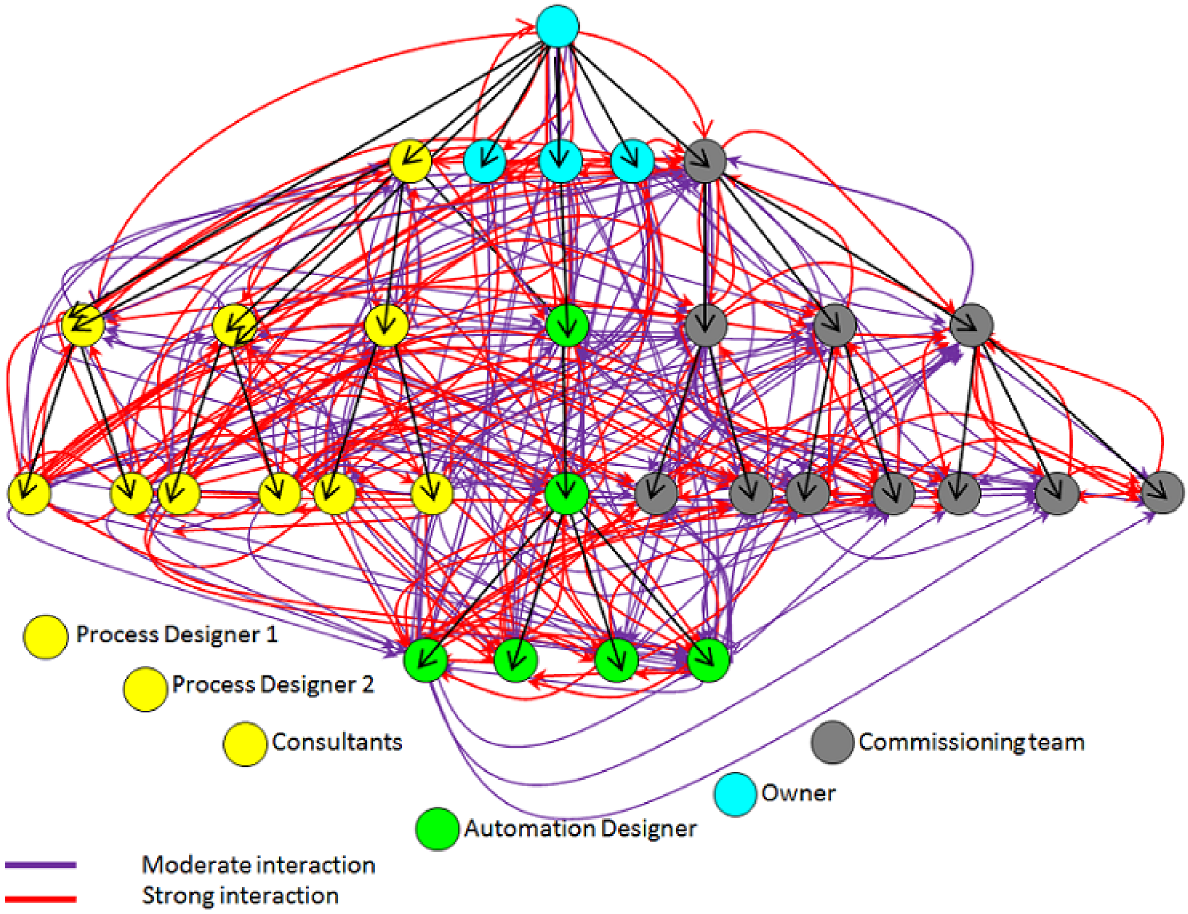

Fig. 3. Graphical representation of hierarchy and communication in the automation project, a reality scheme based on Fig. 2

A suitable tool for it is mapping the trajectory of shortcomings, which is shown in Fig. 4. Possible trajectories of shortcomings with their "mirroring back" to the person giving rise to the shortcoming are mapped with different line types. The shortcomings may be disclosed in any stage of project development and naturally in multiple ways "mirrored back" to all agents in the influence area of this shortcoming. Obviously, the clarification of a shortcoming needs some additional cooperation effort and it gives ~~a~~rise to the synergy level of task solution with the aim of meeting market needs. The key problem of the present research is how to manage these numerous maps, which the next chapter of the paper is devoted to.

4. METHODOLOGY FOR CUTTING DOWN PROJECT DURATION

The precondition for the use of the proposed methodology for the prognosis of project duration for automated factory design and commissioning is the execution of the first level activities of the present research [3]. In this context project duration is also divided into two stages. At first it is necessary to compute the average probabilistic duration of the project proceeding from the statistics of human shortcomings. The second task is to keep the chaos under control by skilled handling with discovered acute shortcomings trajectories.

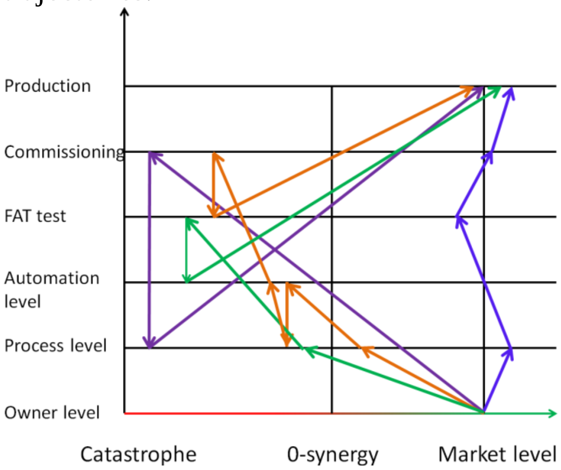

Fig. 4. The shortcomings' trajectories

A thorough analysis of human shortcomings' database, considering the origin of problems in the communication network and the efforts needed for their elimination in shortcoming blocking zones is visualised in Fig. 2. The percentage of effort needed to finalise the project is introduced to the clustered matrix form. The critical percentage, where the communication matrix needs to be improved, was set to 0.3% or one working day of all the time needed for rework. The values below 0.3% were considered as casual problems, which do not need to be regulated.

The analysis shows that the majority of the problems falls to the area of clustered meta-teams A, B, C and D, indicating the need for reforming them in order to reduce communication insufficiency. The most common, company-based team structure is shown with black bordered rectangles. Additionally, there are some problematic areas outside meta-teams, which need special attention. As some of these problematic fields were not considered as part of the scheduled communication map, the matrix needs to be upgraded by new communication marks or increasing communication level. As some new communication schedule marks are located outside meta-teams blocks, it is reasonable to schedule the communication between the meta-teams by appointing liaisons for certain subjects communicated.

Turning back to the current project it is necessary to recognize that the chaos in current hierarchical system communication schedule starts with a single wrong decision or shortcoming in the communication process, inducing the following wrong decisions and therefore exponential growth of chaotic behaviour of the whole system. The trajectory of the actual process starts to differ from the predicted one and causes the multiplying amount of shortcomings in the hierarchical communication system (see Fig. 4). To reduce the influence of chaos, it is necessary to introduce perturbations (additional communication lines or distribution of time inside the project) to lead the process trajectory towards the desired one. Further, it is also necessary to add time and synergy dimensions to the existing scheme All efforts to return trajectories closer to the market level on the synergy scale need some additional cooperation efforts, which lead to the empowering of the synergy of the process concerned in case the most effective strategy is chosen for with an appropriate control of the current result.

The only way to solve the above described entirely probabilistic task is to find a mathematical modelling technology from the field of soft computing [9]. It is a very complicated area as at iterations the new or corrected information can appear at any moment of the process of rework where iterations take place among sequential, parallel and overlapped tasks. At the same time the amount of repetitive work is reducing according to the learning curve. For the solution of the listed problems Discrete Event Modelling seems to be the most promising [10]. This approach allows computing probability distribution of lead-time in the project network and therefore evaluating the effectiveness of the chosen strategy of elimination of the consequences of discovered shortcomings. The results of modelling have shown that it is possible to reduce the average project duration significantly depending on the experience of the project team. For a usual one-and-half-year project this means several weeks of reduced labour costs of automation team plus avoided losses from unreceived production.

5. CONCLUSION

A methodology for the prognosis of the project execution time for hierarchical automated factory design and commissioning teamwork is proposed. The methodology is based on real projects' human shortcomings' database used for the prognosis of the target time to attain the market level performance of the factory. The essence of the methodology is proactive chaos control by temporary chaos mapping and well-timed dynamic empowering of the synergy level by reasonable rework and tune-in. It is shown that by empowering the synergy in teamwork it is possible to cut down the project target time and corresponding labour costs remarkably.

6. ACKNOWLEDGEMENTS

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