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IMPROVED DESIGN METHODOLOGY PRACTICE: SUCCESSFUL MATCHING OF TASKS AND EMPLOYEES

Malte Sebastian HINSCH, Jan Erik HELLER and Jörg FELDHUSEN
Chair and Institute for Engineering Design, RWTH Aachen University

ABSTRACT
Choosing the right employees for a given task has great influence on the quality of the results and the time needed. Executives who have to decide, which employees are best suited for a task, often make those decisions based on experience or emotions. Therefore, these decisions are usually complicated to trace and executives with little or no experience often have difficulties choosing the right employees. Teaching the mechanisms of employee placement provides a solid basis for future engineers' work practice, as the right choice of collaborators is vital for success. The method proposed is especially designed for research and development (R&D) departments in engineering companies. Its purpose is to assist executives in assigning the most appropriate employee to a typical task in their department. Two models and a linking algorithm for the successful allocation of employees enable the assignment. Insights gained in this paper are intended to both improve R&D practice as well as the education of design engineers' education in the future and will be transferred into education practice. Furthermore, understanding the mechanisms behind successful task execution can support better teaching concepts.

Keywords: Design methodology, employee allocation, engineering tasks, research & development

1 INTRODUCTION

Decisions to allocate staff in research and development (R&D) departments are usually difficult to trace and executives with little or no experience find it hard to make the right choice. This paper describes a method to enhance employee allocation in Engineering Design projects, which is especially designed for R&D departments in engineering companies. Its purpose is to assist executives in the following situation: An executive in a R&D department has to assign the most appropriate employee to a typical task in his department. The executive knows the task and he has to choose from a pool of permanent professionals. The proposed method is based on two sub models, one model to categorize the engineering task and one model to consider the employee. An algorithm to perform the assignment of task and employee links both models.

In chapter 2, the state of the art as considered in the model is summarized. The following chapter 3 introduces the prototype for the application of the method. Chapter 4 describes the software demonstrator, which was implemented to validate the method. Its application is covered in chapter 5. Finally, in chapter 6, a summary of the method is given along with an outlook on further development.

2 STATE OF THE ART ON TASK AND EMPLOYEE MODELS

Both, tasks and employees have been extensively analyzed in various scientific fields. In this chapter, a short introduction on models providing the background for this paper's approach will be given.

2.1 Task Model

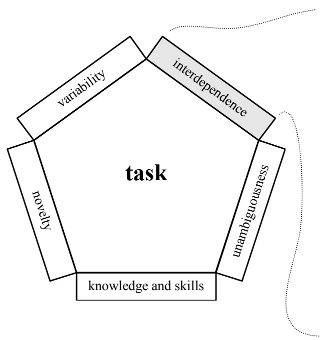
According to Schreyögg, tasks can be subdivided into five basic categories according to the following scheme:

1. Considering the (manufacturing) technology (e.g. welding, turning, etc.)
2. Considering the related object
3. Considering the respective phase (e.g. of the development process)
4. Considering the status (e.g. decision making, planning etc.)
5. Considering the purpose of the task. [1]

Regarding the five given categories, Schreyögg proposes four criteria to describe tasks:

- Variability (quantity and quality of alterations to conditions of task execution)
- Novelty (number of exceptions the task executor faces)
- Interdependence of task (extent of task dependence on actions related to task execution)
- Unambiguousness of task

The model introduced here is based on research originally done by Kosiol [2], as Schreyögg's [1] approach is derived from Kosiol's work. Both Schreyögg's and Kosiol's criteria are enhanced with one additional factor and one criterion will be modified. These modifications consider an approach of Ryschka et al. They propose to take the employees' background and the skills demanded by the task into account. Their approach is divided into three dimensions such as formal education in matters related to the task, more general abilities and social aspects as well as a third dimension regarding motivation and personality traits [3].



1) The solvability of the task depends on previous tasks.
2) Following tasks are dependent on the progress of the task.
3) A single delayed step will delay the whole project (= critical path).
4) Repeated efforts in a single step have no effect on the next single steps.
5) There is a high need for communication.
6) Many persons are needed to work on the task.
7) Task fulfillment requires a high level of employee interaction.
8) An extensive interaction of employees is needed to solve the task.
9) Other people / departments within the company are necessary to achieve the objective (for example manufacturing, computing, ...).
10) Non-available resources are necessary to achieve the objective (e.g. external manufacturing, service ...).

Figure 1. Key characteristics of the task model with detail items for interdependence factor

Combining these approaches, and taking into consideration particular traits of task execution in Engineering Design processes, this paper proposes the five factors to describe a task as shown in Figure 1. In order to obtain an effective visualization of the five factors, these have been arranged in a pentagon. Thus, they can easily be perceived all at a glance, which supports a quick approach among applying users. These five factors will be outlined in more detail in chapter 3.

2.2 Employee Models

Personality traits can be described following the approach of the NEO-FFI-Inventory, as first introduced by Thurstone et al. in the 1930s with their proposal of the "five-factors-model" [cited after [4]]. Borkenau describes the "NEO-five-factors"-Inventory by Costa and McCrae in [5]. An inventory to analyze personality traits of humans usually consists of factors, which in turn are defined by items, sentences with statements to be agreed on or not. These sentences evaluate the subject's approval or disapproval to certain statements and thus evaluate the subject's personality. The original NEO-FFI-evaluation provides five factors to describe the subject's personality:

1. Neuroticism
2. Extraversion
3. Openness
4. Agreeableness
5. Conscientiousness

Twelve items define each factor. Schuler defines sixteen factors to describe personalities [6]. As the approach of the NEO-FFI is more general than Schuler's and other approaches regarding the application of the model described in this paper, it will be used as a basis for this paper's approach. Research on the NEO-FFI has shown that three of the five factors especially affect task execution success. Openness, agreeableness and conscientiousness have been proven to grant a subject's success in work environments [5]. Therefore, these make up the first three factors for the model describing the employee. Weinert proposes to also consider an employee's skills and background [7]. Adding the factors "competence" and "capacity of problem solving" to the employee model achieves this. Similar to the task model as well as the first three factors of the employee model, these factors are defined by items. Figure 2 displays the five factors for the employee model as well as an excerpt of the items for the competence category.

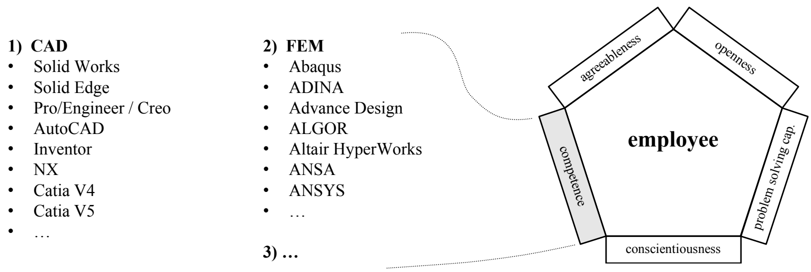


Figure 2. Key characteristics of employee model with detail items for factor "competence"

2.3 Employee allocation

Schuler introduces various ways to allocate employees [6]. This allocation is most often done prior to actual technical task execution (in or by human resource department officials). Therefore it will only be briefly summarized in this section. The allocation as proposed by this paper will take place along with actual practical and daily work in engineering departments. Hell, Boramir et al. describe employee allocation in [8]. Fank summarizes software for employee allocation [9]. It varies from simple software to set up schedules for employees up to specialized software for the administration of thousands of employees considering other systems such as Enterprise Resource Planning Systems.
The allocation of employees as proposed here will be done by evaluating the results of the task model. Subsequently, grades obtained in the employee model will be compared. Mathematical matching will then lead to a proposed employee for the specific task.

3 MODEL PROTOTYPE

A working prototype has been developed for the implementation of the method: It is based on practical experiences in design education at RWTH Aachen University as well as interviews in industry.

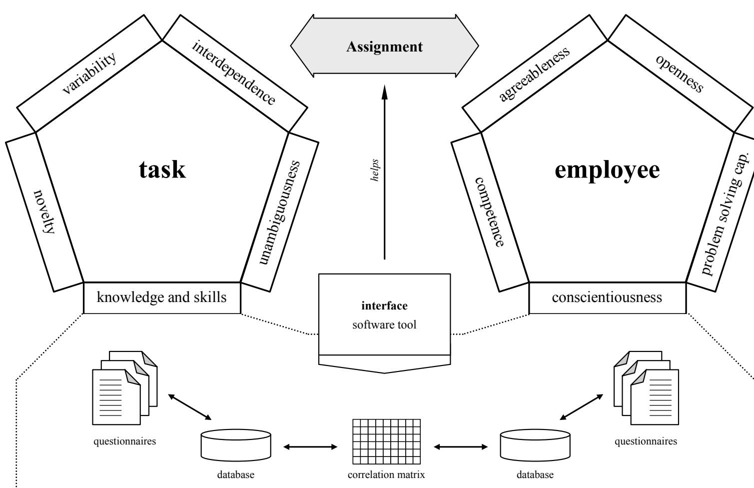


Figure 3. Combined model with assignment software interface and general model structure

Questionnaires to assess the qualifications of employees and the requirements of the task enable a successful matching of task and employee: One questionnaire determines the requirements of the task and the other one classifies the employee.
The questionnaire to determine the tasks' requirements has to be filled out by the executive. It consists of various statements about the task. The style of the statements is derived from items as used in

inventories to describe human characteristics, commonly applied e.g. in psychology. Every statement has to be rated on a five step scale depending on how well it describes the task. Figure 1 exemplarily displays ten questions, i.e. so called items that comprise the overall ranking for the characteristic "interdependence". Catalogues for each factor have been adopted and developed in order to gain a relevant image of the task.

The questionnaire to classify the employee is based on established personality questionnaires such as the NEO-FFI, e.g. used in psychological tests. It has to be filled out using a five step scale by the employee and contains various statements about personality and professional skills. As questionnaires of this kind are very common in companies today, a database already exists in many cases. An excerpt of various skills considered in the "competence" factor is given in Figure 2.

The matching process itself works as an unweight comparison of the combined value for the five factors of the task and the value for the five factors for the employee. For each dimension (e.g. the factors) of the task, a value is determined. Likewise, the factors of the employee are determined. Next, one factor describing the task is referenced to one or more factors of the employee. Relating e.g. novelty with openness is one of the comparisons to be done. This system of comparison is subject to ongoing research at RWTH Aachen University.

The combined model is displayed in Figure 3. Questionnaires are used to fill databases for both tasks and employees. Through the use of a correlation matrix that compares the values for each of the five dimensions the assignment is supported. A software interface helps with filling in all numbers and displaying the result. It is described in chapter 4.

4 SOFTWARE-BASED DEMONSTRATOR

In contrast to the method proposed, existing and established approaches for the assignment of employees often are too universal to fit the special requirements of R&D departments. By our method, practical and abstract psychological qualities of employees can be measured and compared to the requirements of a task. The result is a well-arranged list of all employees that are capable of solving the engineering task. This facilitates the daily routine of executives in engineering and leads to more efficient task execution. To overcome the described shortages and to adopt the model developed, a software prototype has been set up. Corresponding to the model it also consists of three main parts: a module for describing tasks, a module for classifying employees and a module for allocating tasks and employees. A fourth module is conceptualized in addition to display the results of the allocation procedure.

4.1 Module for task evaluation

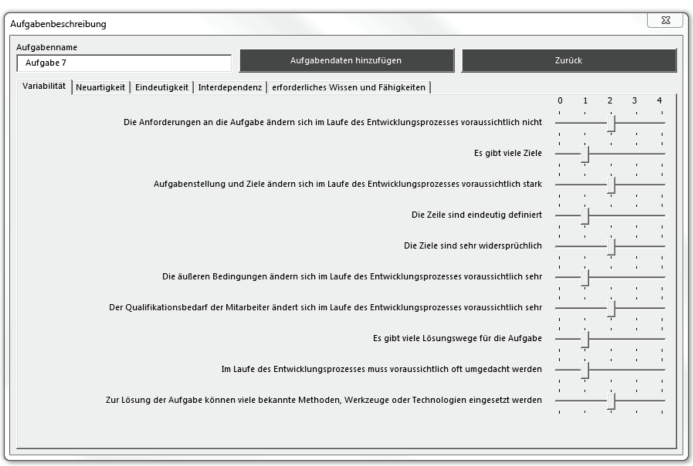


Figure 4. Input dialog of software prototype for task evaluation

Figure 4 displays the input dialog of the software prototype for the task evaluation module. According to the model presented in section 2.1, the five categories are implemented as five pages or tabs. Each of the pages offers the items written in concise sentences, where the executive can specify the requirements of the task in detail with a slide control. To achieve comparable results, every slide control is divided into five steps ranging from 0 to 4, with 0 meaning disagreement with the items and 4 meaning complete agreement. In addition to the input dialog, the software prototype offers an overview list of all tasks already entered into the database.

4.2 Module for employee classification

To implement the employee model, a similar approach has been chosen. In addition to an overview list of all available employees, an input dialog has been conceived for entering relevant information for the employee regarding the five factors and the corresponding items presented in section 2.2. Analogous to the dialog box displayed in Figure 4, slide controls for entering values from 0 to 4 have been implemented on each of the five pages corresponding to the five factors.

4.3 Module for allocation of task to employee

The result of the matching process is a list of all employees that are available for the executive to be allocated to the specified task. Figure 5 displays the result interface for an exemplary matching process with eight employees to be matched with one task. The executive is able to choose the desired task from a list box located at the top left of the window. The required values for the five factors of the task are shown next to it, e.g. a value of 1.25 for the factor of variability.

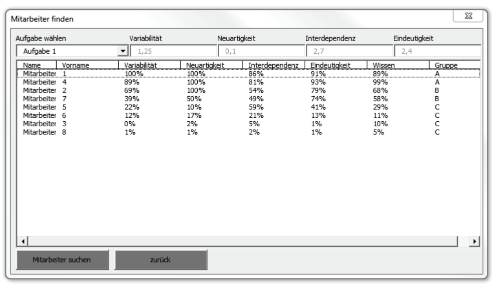


Figure 5. Result output interface of the matching algorithm module

The main area is covered by a list featuring all employees ordered by their overall rank. For each factor the compliance is displayed as a percentage. For example, the employee named "Mitarbeiter 4" offers a compliance value for variability of 89 per cent. In the current implementation a non-weighted overall rank is calculated by estimating the arithmetic mean of the five compliance values. For easy application, all employees are clustered into three groups similar to a pareto-analysis ranging from best-fit (A group) over good-fit (B group) to a non-optimal fit (C group). However, issues that are not covered by the methodology presented here are the actual workload, the utilization of the employees and the available capacity. Nevertheless, the architecture of the software is designed in an open way to allow the integration of other information. Legal issues within human resources management are not covered either as this proof of concept covers the general applicability of the model developed.

5 APPLICATION

This paper's approach was validated in two ways: First, aspects of the approach have been proven valid in a series of lab studies with engineering students at RWTH Aachen University, as described by Hinsch et al. in [10], [11], Djaloeis et al in [12], and Duckwitz et al. in [13]. Furthermore, a series of interviews was held with engineering company executives, responsible for R&D departments. Both lab studies and interviews showed the applicability of the approach. Several publications of the authors, among them two at E&PDE'13 will further describe the lab studies conducted to develop the method [14], [15], [16].

6 CONCLUSION AND OUTLOOK

This paper introduces a method for successfully assigning employees to engineering tasks. The method is based on two models that are linked by an algorithm to assign task and employee. One model is intended to categorize engineering tasks, whereas the second model provides a description of the employee. First, a short overview on task and employee models and approaches for allocation is given. Subsequently, the models and the algorithm are introduced. To define the algorithm in more detail, results from a lab study undertaken by the authors as mentioned in chapter 5 will be evaluated regarding the success in task execution and personal background. The series of interviews held with engineering company executives (see chapter 5) provides additional input. Finally, the method is presented along with the software demonstrator. With the method proposed in this paper, both executives and employees will benefit from higher job satisfaction provided by better fitting tasks. In application certainly this method has to be combined with responsible action by the applying executive to minimize mismatching. The described prototype enables teachers and executives alike to better understand mechanisms of task and employee matching and thus enhances engineering design methods' application. This study is part of a larger-scale research field at RWTH Aachen University aiming at the application of Systematic Engineering Design in engineering companies as well as in education.

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