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Vorwort

Das Tätigkeitsfeld des Fraunhofer Instituts für Techno- und Wirtschaftsmathematik ITWM umfasst anwendungsnahe Grundlagenforschung, angewandte Forschung sowie Beratung und kundenspezifische Lösungen auf allen Gebieten, die für Techno- und Wirtschaftsmathematik bedeutsam sind.

In der Reihe »Berichte des Fraunhofer ITWM« soll die Arbeit des Instituts kontinuierlich einer interessierten Öffentlichkeit in Industrie, Wirtschaft und Wissenschaft vorgestellt werden. Durch die enge Verzahnung mit dem Fachbereich Mathematik der Universität Kaiserslautern sowie durch zahlreiche Kooperationen mit internationalen Institutionen und Hochschulen in den Bereichen Ausbildung und Forschung ist ein großes Potenzial für Forschungsberichte vorhanden. In die Berichtreihe sollen sowohl hervorragende Diplom- und Projektarbeiten und Dissertationen als auch Forschungsberichte der Institutsmitarbeiter und Institutsgäste zu aktuellen Fragen der Techno- und Wirtschaftsmathematik aufgenommen werden.

Darüberhinaus bietet die Reihe ein Forum für die Berichterstattung über die zahlreichen Kooperationsprojekte des Instituts mit Partnern aus Industrie und Wirtschaft.

Berichterstattung heißt hier Dokumentation darüber, wie aktuelle Ergebnisse aus mathematischer Forschungs- und Entwicklungsarbeit in industrielle Anwendungen und Softwareprodukte transferiert werden, und wie umgekehrt Probleme der Praxis neue interessante mathematische Fragestellungen generieren.

Prof. Dr. Dieter Prätzel-Wolters
Institutsleiter

Kaiserslautern, im Juni 2001

SIMULATING HUMAN RESOURCES IN SOFTWARE DEVELOPMENT PROCESSES

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KEYWORDS

Human resource modeling, software process, productivity, human factors, learning curve.

ABSTRACT
In this paper, we discuss approaches related to the explicit modeling of human beings in software development processes. While in most older simulation models of software development processes, esp. those of the system dynamics type, humans are only represented as a labor pool, more recent models of the discrete-event simulation type require representations of individual humans. In that case, particularities regarding the person become more relevant. These individual effects are either considered as stochastic variations of productivity, or an explanation is sought based on individual characteristics, such as skills for instance. In this paper, we explore such possibilities by recurring to some basic results in psychology, sociology, and labor science. Various specific models for representing human effects in software process simulation are discussed.

1. INTRODUCTION

During the last few years, simulation has become an important approach for modeling and analyzing software development processes (see Kellner et al. (1999)). Most of the models discussed in the literature are of the system dynamics type, which is well-suited for representing and utilizing the cause-effect-relationships between various variables related to software development processes. Typically, such models are based on aggregated variables such as, for instance, total workforce, total amount of work, or total number of defects.

Such a level of abstraction is appropriate for a rough estimation of overall project variables such as duration, effort and costs, but does not solve typical tasks of a project manager such as deciding on process alternatives (e.g., inspecting a design or code document, testing a module), assigning tasks to persons, or scheduling the various activities. Simulation models with an explicit representation of objects related to software development processes, i.e. items (design or code documents) and developers, might be better suited for supporting these decisions. Typically, discrete-event simulation models allow for such an explicit representation of a multiplicity of objects of the same type.

In two research projects we dealt with the development of discrete-event simulation models of software development processes (see Neu et al. (2002, 2003)). During these projects, we faced various problems related to the rather detailed level of modeling, especially problems related to an adequate representation of persons (developers) participating in the processes. When considering human-based models of software development processes we found that few established approaches exist and that some models appear to have an ad hoc character (mainly because of a lack of empirical data available for validating models). For these reasons we consulted empirical results from psychology and other fields and tried to employ reasonable (but still simple) models for considering the most important effects related to software developers. In this paper,

we focus on human modeling as used in the discrete-event simulation. Other aspects of the discrete-event simulation model such as the modeling of artifacts (code documents), the representation of the activities coding, inspection, test, and rework, and the organization of the overall process (assignment of staff, scheduling) are not treated in this paper, but can be found in Neu et al. (2002, 2003) and Hanne and Nickel (2003).

The paper is organized as follows: In Section 2, we review various empirical results from psychology, sociology, and labor science. In Section 3, related work on modeling human factors in software development processes is discussed. In Section 4, some of our approaches to human performance modeling in discrete-event simulation are presented. With respect to this model scope and available or obtainable data, we concentrate on models for learning and time pressure effects. Moreover, aspects of the overall simulation model and the utilization of stochastic elements are discussed. In Section 5, some experimental results from the simulation model are presented. The paper ends with the conclusions in Section 6.

2. PSYCHOLOGICAL ISSUES

As well known, software development is a human-based intellectual activity. The outcome of a person's activity (spending a specific amount of time, e.g., for writing source code, for inspecting a document, or for testing a module) may depend on a large number of factors including random ones. In the following we discuss those factors which appear to be the most important with respect to software development.

2.1. MEASURING AND MODELING THE PRODUCTIVITY

One of the most obvious aspects related to persons being represented in a production process is their productivity. In general, productivity is defined as the amount of output per unit of input. With respect to labor, the input is usually measured in time units (e.g. hours) of work. The considered activities are, e.g., writing, inspecting, or testing source code (or other software artifacts). In these cases, the output can be measured by the accomplished size of the source code. For determining the size, various measures have been discussed in the literature. Here, we do not take up this discussion but stick to the most commonly used measure, the lines of code (loc) of an item.

Thus, knowing a person's productivity (measured in loc/h) and the amount of work to be done (measured in loc) allows simply to calculate the required time for that task and thus one of the most important human-related variables of the simulation model. A main problem related to this consideration is, however, that personal productivities cannot be regarded as being constant over time. Moreover, there are great variances in the productivities among programmers and, in general, theses productivities are not well understood (see Johnson (1988)). For these reasons, we also considered empirical results on explaining productivities from other fields of intellectual activities. Some key results are discussed in the following.

In general, the analysis of the factors influencing the productivities - either in field studies or in controlled experiments - shows various problems. While laboratory experiments may be problematic with generalizing their results to practical situations, field studies may suffer from effects of various (and possibly unknown) interdependent variables which cannot be isolated.

2.2. ORGANIZATIONAL FACTORS

Important impacts on the (motivation and) performance are due to interpersonal relationships of an organization as analyzed in Welsch (1974) and summarized below. The interpersonal relationships, some of them being formal, others being informal, may be distinguished into social and communicative ones. Among the social relationships there are, for instance, aspects of the size of an organization, the leadership style, the hierarchical structure, horizontal co-ordination (co-operative vs. competitive), and the cohesion between staff members in general.

With respect to the size of an organization (i.e. a team of persons working together) opposed effects can be expected (Welsch, p. 40ff): On the one hand, an increasing size allows for a better division of labor and specialization of people. On the other hand, a high division of labor may lead to more monotony and fatigue or less-motivated persons. With a larger size, control and communication overhead usually increases while, at the same time, some group potential cannot be utilized. All these effects reduce the group efficiency. Empirical results, however, do not show clearly what an optimal group size might be. The optimal size may depend on various other variables such as, for instance, the specific tasks to be done and the relationships within the group.

In a similar way, there are no clear results with respect to the leadership style. Although there are results indicating advantages of a democratic or participating leadership style, there are also experiments which do not show significant results or which indicate that too much "laissez faire" might be unfavorable. Experiments have also indicated that personal and external factors contribute to the influence on productivity.

With respect to the interdependence between employees, there are some indications that cooperation is favorable compared with, at least too much, competition. With respect to the hierarchy of an organization, there are studies showing that too much hierarchy is contra productive, at least for small teams. No hierarchy, on the other hand, is also not favorable. These results are approved by experiments on the communication structure of a team which show that some centralized communicator leads to a higher productivity than in the case of a totally uncentralized communication. With respect to the cohesion (which is anyway difficult to formalize) of a system and its effects on productivity there were no significant results observable. If the job satisfaction is high and the group atmosphere is good then cohesion should be favorable with respect to productivity. If this is not the case, a high cohesion may lead to fatigue, inactivity and low motivation.

A main result with respect to most organizational factors is that their influence, in general, cannot be determined. Their influence depends very much on the specific nature of the tasks to be done and the situational environment of performing the task. Many aspects of the organizational structure and the specific situation cannot well be measured for predicting their influence. Moreover, there are various dependencies between the influencing factors. Because of these reasons (and because of the non-quantitative nature of various of these factors), the influence arrows of the factor shown in Fig. 1 are labeled with "S" (instead of "+" or "-") which indicates the specificity of their influence.

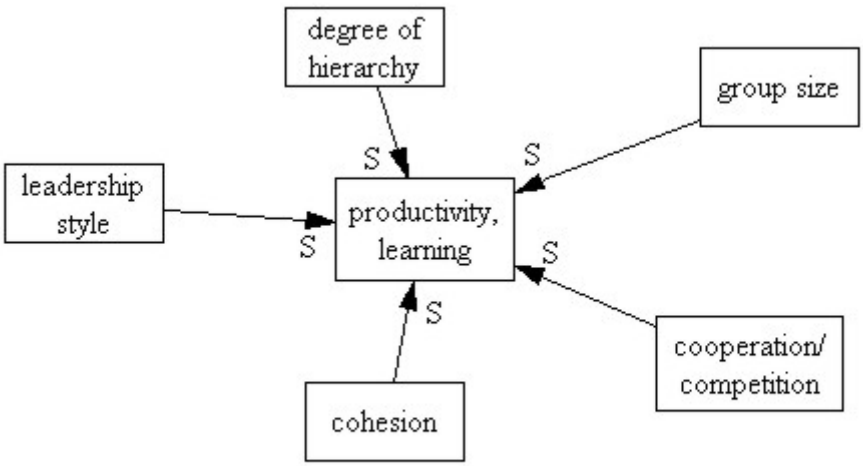

Fig. 1: The Influence of Organizational Factors.

A study investigating the productivity of intellectual activities with respect to group and organizational factors was done by Mittenmeir (1986) who analyzes the variables influencing the productivity of a research unit (team). First of all, the problem of measuring the productivity using various qualitative and quantitative factors is discussed. Secondly, cause variables specific to a research unit are discussed. The possible factors can be divided into the following groups: personal resources, material resources, and information. The considered factors are, for instance, the number of researchers and technicians, the degree of fluctuation, the satisfaction of the team with respect to their resources, visits from/to other research units, or conference participation. Mittenmeir analyzes their influence by a linear regression model but factors specific to the individual researchers are not considered.

The results of that study are not that clear. With respect to the information exchange, there is a clear positive relationship to the group productivity. This variable is, however, not considered to be an independent one but rather a mediator variable subject to some feedback effects. With respect to the quantitative variables such as size there are positive relationships but their weights are quite variable which indicates other factors being relevant. It is assumed that the intellectual productivity of a team is highly situation-dependent and dependent on the single persons.

In the following we will sustain from a further discussion of group and organizational factors. These can be considered in the simulation model by global parameters for tuning a model e.g. values for average or maximum productivities. Instead, the focus will be on factors individual to a software developer. These factors are of specific consideration not only because of their importance but also because the intended model represents the developers as autonomous objects (moving items).

2.3. SKILLS, EXPERIENCES, AND LEARNING

Individual experiences and skills belong to the most widely discussed factors influencing personal productivities. Field studies, such as Cheney (1984) which analyze various influencing factors, show that experiences have a most significant effect on a programmer's productivity. Moreover, there is a definite psychological evidence of a variety of skills of developers (see Wilson (1988)). These skills may depend on the domain (e.g. GUI application, database applications, etc.) of the artifact and the phase of its production (design, coding, test, ...). For some part, these skills may result from individual intellectual and other capabilities, for the other part, skills may result from experiences in the considered field. In some studies (see, e.g., Cheney (1984)) mathematical capabilities, for instance, are found as not so important with respect to programmers' productivity while experiences are of outstanding significance.

With respect to the experiences, it is generally assumed that due to learning effects the productivities steadily rise during the time spend for similar activities. This mechanism is also called ‘learning by doing’ or autonomous or first-order learning. The effect of accumulated time spent for production is reflected in the well-known learning curve (see Anthes (2001)) which expresses the unit production costs as degressively decreasing with the accumulated production. In Fig. 2 two prototypical forms of learning curves are shown, one with decreasing learning effects, the other one being S-shaped.

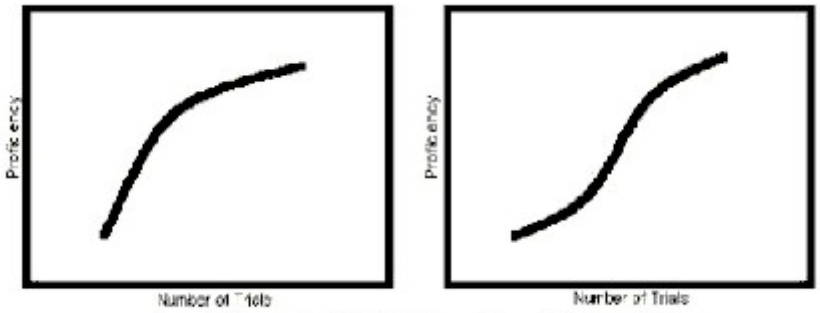

Figure 1. Decreasing Rate of Return **Figure 2. S-shaped Curve**

Fig. 2: Typical Learning Curves (see Kanter and Muscarello (2000)).

This relationship expressed by the learning curve was first discovered for the US aircraft industry in the 1930s. In this and similar studies for the manufacturing industry it was found that with the doubling of experiences (or cumulated production) the productivity increases by about 15 to 25%.

Compared to that, the learning effects in the software industry are on average rather low: Costs are declining approximately 5% per year while the semiconductor industry, for instance, shows a decline of about 48% (see Lewis (1996)). Experiments (see Sherdil and Madhavji (1996)) have shown that the learning rate can significantly be improved by supplementing the 'learning by doing' by specific technology injection also denoted as second-order learning.

2.4. STRESS

Unlike experiences which show long-term and usually positive effects on productivity there may be various causes of shorter-term (positive and negative) fluctuations in productivity. A main short-term effect on productivity may be caused by emotions. As, for instance, discussed in Pekrun (1992) emotions play a significant role as cognitive and motivational mediators determining achievement and learning. In general, a variety of emotions may be relevant for a person's achievements in performing tasks, for instance enjoyment, hope, relief, pride, gratitude, boredom, anxiety, or disappointment. Also emotions relevant to the social context are influential, e.g. gratitude, empathy, sympathy, anger, envy, or contempt. While mostly the effects of positive emotions on achievement are rather clear (i.e. positive effects), the effects of negative emotions may in part be negative, but to some extent also positive. In many cases, the specific effects of emotions depend on the tasks to be done and, possibly, other characteristics of the situation.

With respect to boredom, the effects are rather clear: Boredom leads to a reduced intrinsic motivation and an engaging in different activities, thus to a reduced productivity. Other negative emotions may have an activating effect which may influence productivity simultaneously in positive or negative ways. Anxiety, for instance, may increase the extrinsic motivation (i.e. avoiding an undesired outcome) while, at the same time, it may induce blockages and decrease the intrinsic motivation (i.e. doing something for the sake of itself). The net effect of such contradictory mediators is situation-dependent. For instance, when the current progress of a project is insufficient, effects of a reduced intrinsic motivation may or may not be compensated by extra hours of work for avoiding negative consequences of a project failure. In Fig. 3 some typical causal relationships between emotions and productivity are shown.

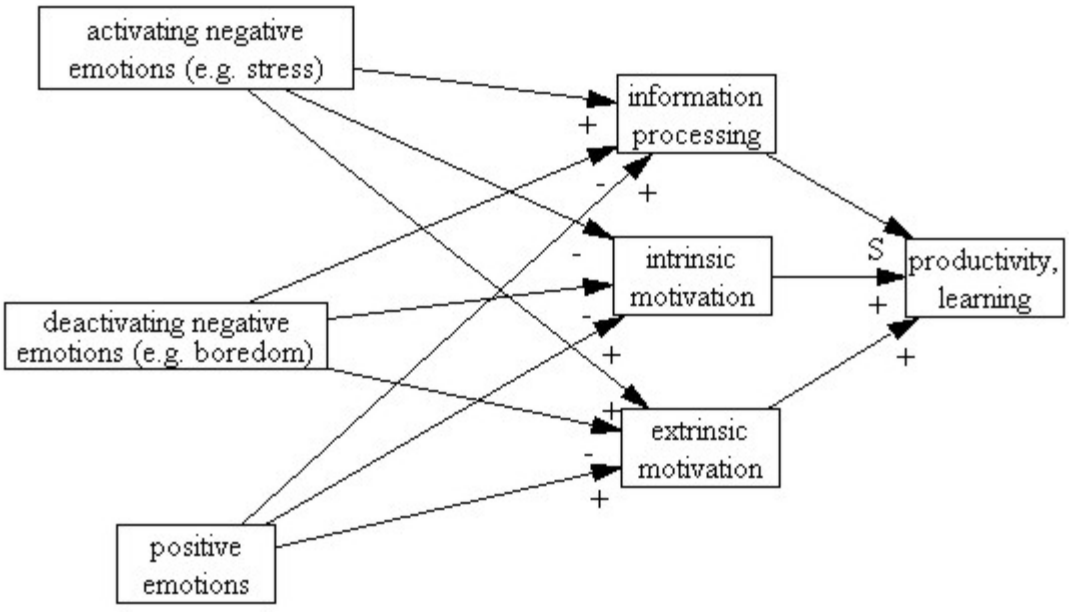

Fig. 3: Model of the Emotional Factors.

With respect to the application domain, the development of software, we assume that a significant part of emotions may be caused by circumstances outside the working environment or are not specifically controllable (e.g. social interactions between employees). Moreover, modern leadership styles may avoid faults such as, for instance, a too authoritarian control which constricts the scopes of the employees and deteriorates the motivation.

Instead, we assume that the organizational factors are suitable, at least that these are 'adjusted' (i.e. being fixed for a specific project) such that they can be neglected in software development models discussed below (or that they are considered by a parametric fixing of the model). Instead, we focus on the consideration of fatigue, stress, time pressure (pressure to perform), and boredom as factors being coupled with the execution of a specific project. These factors are discussed in the following.

With respect to fatigue there is no generally accepted definition in the psychological literature (see Slanar (1982)). For some part, there are conceptions based on 'energy models' describing fatigue as resulting from an exhaustion of an individual's energy by the endurance and heaviness of a job. On the other hand, motivational factors are essential for a subjective fatigue which may be caused by imposed bondages, the monotonicity of a job, or a lack of sociability during work. In a similar way, saturation (and over saturation) may be caused and result in negative affections towards work.

In psychological research, stress is mostly considered as some kind of distracting perception. Laux and Vossel (1977), for instance, analyze stress in the sense of distraction or delayed language feedback. A standardized test/experiment (KLT) was conducted to analyze training effects in intellectual performance (solving of math equations). The experiments show that stress experience increases the productivity for future stress situations, even if the stressor is different. Although with respect to software development rather the pressure to perform is of interest than a perception-based stress, the above psychological results may be conferred. Compared with stress, effects of the pressure to perform usually take place on a larger time-scale, i.e. during days, weeks, or months. In Section 4.3 we discuss a specific model for considering boredom and stress as the effects of time pressure being coupled to the specific progress of a software development project.

3. RELATED WORK

Several authors describe human resource management or models for human resources in software process models. These approaches can be distinguished into two categories; first, models that treat the participants in the model as one or two groups of equal persons, and, second, individual modeling of each participant in the process. The first approach is common in system dynamics models because individual modeling of the persons would lead to a complicated model. The second approach is realized in models with different simulation methods, e.g., discrete-event models or generalized stochastic Petri-nets.

Abdel-Hamid and Madnick (1991) propose a model for human resource management as part of their system dynamics model. They divide the workforce into two groups, the experienced and the newly hired (inexperienced) people, with some of the productive time of the experienced personnel being needed to train the inexperienced personnel. Hiring new personnel, removing personnel (by management to other projects) and people quitting are modeled with delays. The learning curve for becoming an experienced person is modeled by an assimilation rate that describes the time it takes to acquire the necessary knowledge. The curve is modeled as a first order exponential delay.

A similar model, called two level promotion chain, is proposed in Sterman (2000). This model is for a more general use to demonstrate a worker training with two levels of experience. This model can be easily extended to more than two experience levels, each with a different learning curve between two levels.

Rus (1998) incorporates a learning factor into the production activity and the validation & verification activity block. The learning factor is modeled as an (unexplained) graphic function and is multiplied with the average productivity to get the actual productivity.

In the approaches above, the participants in the process are treated equally. It is not possible to model individual abilities or learning curve parameters. This behavior is sufficient in models that show a more generalized or upper management view of the process. In models that need to show a more detailed picture, e.g., for scheduling or decisions based on individual attributes, this is not sufficient.

A more detailed view on the learning curve in software development process simulation is given in Hanakawa et al. (1998). They propose three sub-models for modeling the learning curve. The activity model captures the type and difficulty of the tasks to be done. The productivity model shows the productivity of the developer in the context of his or her individual knowledge and the knowledge level needed for a specific task. The knowledge model depicts how much knowledge the developer gains by executing a task where a specific knowledge level is needed. The simulation model has seven steps plus step 0 for initialization. An activity is selected (Step 1), then productivity is computed (Step 2). The accomplished work from the activity model is subtracted (Step 3) and the quantity of gained knowledge is calculated (Step 4). According to the gained knowledge, the knowledge level is updated (Step 5) and the productivity level in the productivity model is updated (Step 6). Depending on the remaining activities, the model ends or starts for the next time increment at the beginning (Step 7).

The authors are conducting several case studies for predicting development time under different settings for the developers. They also show the increase of the developers' knowledge (learning curve) during the simulation. Besides the parameters of the knowledge model, the selection policy for the activities to be accomplished and the shape of the activity model (distribution) have great impact on the learning curve. With normal distribution in the activity model and a random selection policy the learning curve is similar to the one we propose in Fig. 5 below.

In Hanakawa et al. (2002) the authors use the same model as in Hanakawa et al. (1998). They add cognitive maps to describe the structure of individual knowledge of the developers. The same maps are used to map the project workload to certain areas of knowledge. With this addition, the developers' level of knowledge can be simulated for different areas in the cognitive map.

Christie and Staley (2000) are modeling issues associated with the social dynamics of requirements development. The authors use social skills for describing people in a discrete-event simulation model for simulating teams creating requirement documents. Three skills are modeled to describe the technical and domain experts: technical capability, ability to convince (influence), and considering ideas of others (openness).

The skills of the supporting roles (leader, facilitator, scribe) include enabling agreement and modifying the skills of the technical personnel. These characteristics are modeled using a real uniform distribution in the range of 0.0 to 1+x, where x takes on a small positive value. Even if a learning curve is not explicitly modeled, the constant value x has the effect of a learning curve because it increases understanding during the sessions and leads to a better quality of the requirement documents.

4. HUMAN-BASED MODELS FOR DISCRETE-EVENT SIMULATION

In this Section we discuss some of our behavioral submodels used for creating discrete-event simulation models of software development processes. With respect to this model scope and available or obtainable data, we concentrated on models for learning and time pressure effects.

4.1. A VARIETY OF SKILLS

A key assumption of our model is that specific skills determine personal productivities (i.e., the speed of work) on the one hand, and, on the other hand, the quality of work, for instance, the produced number of

defects during coding or the found number of defects during inspection and testing. Since productivity-oriented and quality-oriented skills do not need to be the same for a person or evolve synchronously, we distinguish between these two types of skill values in the model (see bottom level of Fig. 4). For instance, the specific skill values for a developer *j* of the model are the coding quality skill (cqs_j), the preparation (inspection) quality skill (pqs_j), the testing quality skill (tqs_j), the coding productivity skill (cps_j), and the preparation productivity skill (pps_j).

For ease of use we assume these skill values to be calibrated on a nondimensional [0,1] interval. A skill value of about 0.5 is typical for an average developer, while a value near 1 characterizes an experienced or high performance developer. Multiplied with given values for a maximum quality of work or a maximum productivity (corresponding to skill values of 1), a person's actual defect (production, detection) rate and productivity can be determined. Thus, the following model parameters with respect to productivities are used: maximum coding productivity, *mcp*, maximum preparation productivity, *mpp*, and maximum testing productivity, *mtp.* With respect to defects, the following model parameters are used: The number of defects in relation to the size of the document to be produced is expressed by minimum defect density, *mdd*.

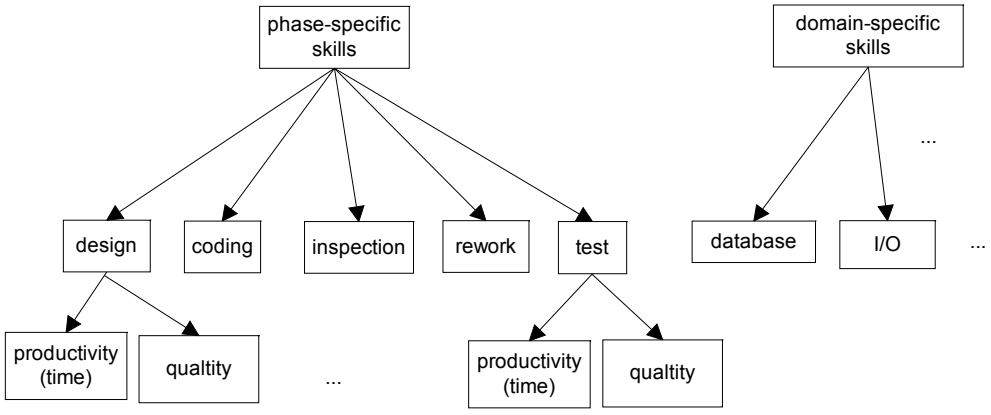

Fig. 4: Structure of Skills

4.2. LEARNING

In the simulation model, the skill values of software developers are dynamically varied by employing a learning model. The learning mechanism is based on a logistic growth model. According to the pure logistic model, a minimum value of 0 and a maximum value or 1 is assumed with a continuous monotonic growth of the corresponding skill output variable (see Fig. 5).

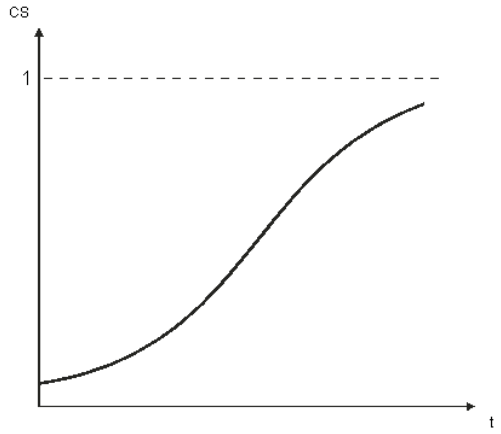

Fig. 5: Logistic Growth of Skills

Let Δt denote the time used for an activity that involves the particular skill, thus the time elapsed since the last update of that skill. For small values of Δt, changes of the skill value can be described by

$$\Delta skill := lf \ \Delta t \ skill_0 \ (1 - skill_0)$$

where *lf* is a learning factor specific to the particular skill, which depends on the institutional environment and personal factors not explicitly considered in the simulation model. $skill_0 > 0$ denotes the skill value prior to the considered activity. For arbitrary values of Δt, the logistic growth of skills is defined by

$$\Delta skill := 1/(1+(1/skill_0 - 1) \exp(-lf \ \Delta t)) - skill_0.$$

If an activity involves several skills (e.g., phase-specific and domain-specific skills), all of them should be updated after finishing the activity. The factor *lf* determines the steepness of the learning curve and thus the time needed to get from a low skill value to a high skill value. Therefore, it reflects the average learning capability of a software developing organization and depends, for instance, on the degree of re-usability of former artifacts.

4.3. TIME PRESSURE, FATIGUE AND BOREDOM

For taking another main effect on personal productivities into account, we have developed a time pressure model for capturing some motivational effects related to fatigue and boredom. Considering a standard level of workload and time pressure, it is assumed that an increase of time pressure first leads to an increase of productivity. For instance, people work more concentrated, social activities are reduced or voluntary overtime is done. This, however, can usually only be expected for a limited period of time and to some specific extent. Excessive time pressure leads to stress and negative motivation of personnel coupled with a decrease of work performance to below the standard level.

On the other hand, not enough time pressure results in underperformance of the staff, who may use extra time for extending social and other activities. Boredom due to working requirements that are to low, may also decrease motivation and, thus, productivity.

These effects are expressed in Fig. 6, which shows a time pressure factor measured on a non-dimensional nonnegative scale and depending on the deviation of planned time t^* to elapsed time t for the current activity, i.e. $t-t^*$. If the activity is behind schedule ($t>t^*$), then first positive and later negative effects take place. If the fulfillment of the plan is easy ($t<t^*$), boredom shows some negative effects. Such a relationship can be expressed, superimposing two logistic functions, i.e., functions of the type

$$y_{1,2}(x) = a + b/(1+\exp(c \ (d-x));$$

$$tp = y_1(t-t^*)+y_2(t-t^*)),$$

one of them expressing the effects of boredom, the other one reflecting the effects of a backlog with respect to the planning. These two functions are calibrated with assumptions on the standard level (tp=1) for a deviation x=0, assumptions on the activation levels for extreme boredom, extreme backlog, and peak performance, the steepness of stepping inside these effects, and the mutual deferment of the effects. In Fig. 6, for instance, the boredom level is approx. 0.75, the overload level is approx. 0.63, the peak level 1.13, the steepness toward boredom level is smaller than towards overload level, and the deferment between these transitions is about 12 on the x-axis (which may be measured in working days). Note that similar functional relationships of transitions between different states can be found for various biological (and other complex) systems such as, for instance, cells.

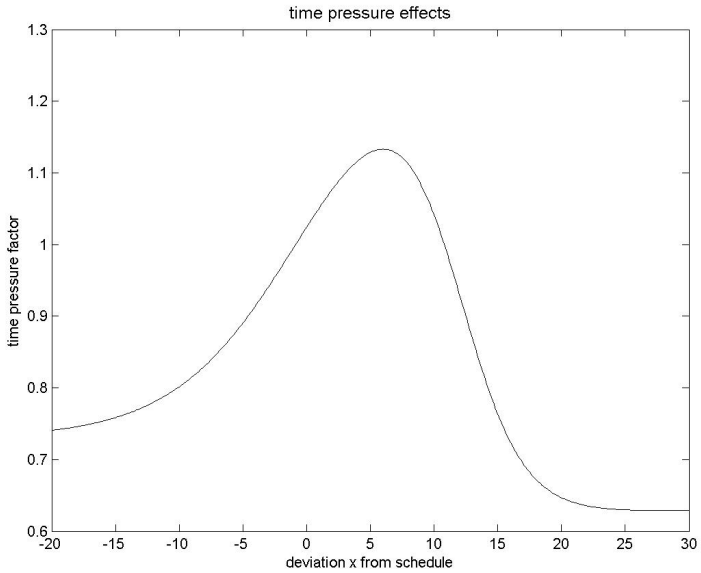

Fig. 6: Plan Deviation and Time Pressure

For a practical application of this model, it is, however, not easy to obtain the values of t and t^* and other parameters for fitting the function of tp. Assuming that there is not a specific set of tasks assigned to a person, individual delays are balanced by team colleagues being faster. Then, time pressure only results if the team's accomplished workload is behind the planned workload. Or in other words: The workload managed at the current time t is larger than a planned or estimated time t^*. Therefore, it is necessary to estimate the time needed for each task prior to the start of the simulation. During a simulation run, it is necessary to do some bookkeeping of accomplished tasks, i.e., an updating of t^*.

Let us note that the basic characteristics of the above function correspond to general assumptions on the psychological relationship between activation and performance according to Welford (1970).

4.4. INSPECTION TEAM PERFORMANCE

While most activities in software development are assumed to be done on a rather individual basis (i.e., one task is assigned to one person), inspections are usually done by a team of persons working on the same document. Even if inspection in a closer sense (i.e., reading the document) is done individually, the outcome obtained by a meeting where the errors found are collected is group-specific, since the collectively found number of errors is usually not the sum of individually found errors (esp. because of double-counting).

For an individual inspector k, it is assumed that the probability of finding a defect is a result of his or her defect detection skill, $dds_k \in [0,1]$, multiplied by a factor, itf, expressing the effectiveness of the specific inspection technique and the influence of other organizational factors. Empirical results of the influence of such organizational factors on the inspection results are provided, e.g., in Biffl and Gutjahr (2001).

Applying the individual defect detection probability, inspector k's individual probability of overlooking a defect is $(1 - itf\ dds_k)$. For the inspection team, the effect of double-counting found defects is considered by using the team probability of overlooking a defect (which is the product of the individual probabilities under some independence condition) for calculating the number of found defects:

$$fd^1_i = pd_i(1 - \Pi_{k=1}^{no\_inspectorsi}\ (1 - itf\ dds_k))$$

4.5. COMPOUND MODEL AND MODEL FITTING

The most important relationships between human factors, factors specific to the tasks or artifacts, productivity, and outcome-related variables (effort, change of defects) are summarized in Fig. 7.

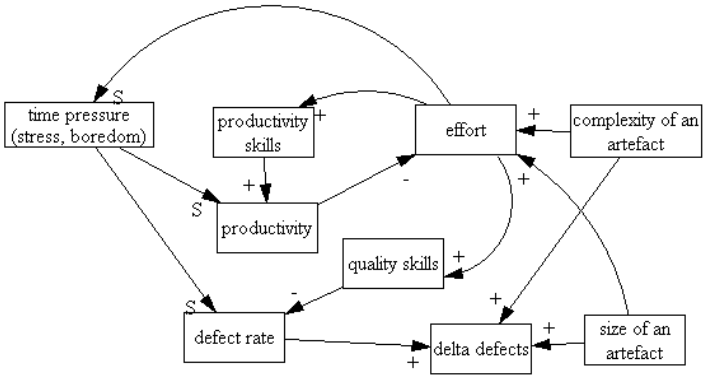

Fig. 7: Rough Influence Model of Personal Factors.

Since the average productivity of programmers can be predicted better than individual ones (see Johnson (1998)), one may use the concept of a "standard programmer" without extensive collection of data. For instance, assuming a given maximum productivity of a person, *mcp*, e.g., *mcp* = 30 loc/h, the actual productivity may be given by

$$cp_k = tp_k \, mcp \, cps_k$$

An average productivity may then serve to calculate typical values for cp_k, assuming that the time pressure factor is 1 on average. The organizational factors are expressed in the values for maximum productivities, etc., which are assumed to be fixed for the given project. For setting these values of the given model, real-life data from industrial software development processes should be used.

4.6. STOCHASTIC EFFECTS

Even after careful refinement of the quantitative relationships in a model of human effects in software development processes, there are essential impacts on productivity that cannot be fully determined a priori, for instance, individual factors such as fatigue, boredom, and other physical and mental factors. These human factors may be considered by stochastic elements in the process, which influence, for instance, the working times and numbers of defects produced (quality of work). Therefore, the results of an activity with respect to the changed number of defects and the time needed for performing it are considered as being partially random.

For this reason, the above productivity and quality variables (according to a deterministic model) are multiplied by random factors. These factors are assumed to be stochastically determined according to a lognormal distribution with an expected value 1. One main reason for choosing this type of distribution is that typically, undershootings of the expected value are rather small while overshootings may occasionally become tremendous. Other aspects of using the lognormal distribution in modeling are, for instance, discussed in Mitzenmacher (2001) and Jordan (1995).

Multiple runs of the model can be used for estimating the effects of such random influences on the distribution of the model outputs, especially with respect to the objectives quality, project duration, and costs. Using such information, a project manager may get a better feeling for the risks within a scheduled project, e.g., by considering a worst-case scenario within a 95% confidence interval.

5. SOME EXPERIMENTS WITH THE MODEL

Together with other components for simulating the handled items (source code artifacts) and the organizational process (assignment and scheduling of tasks) the model has been implemented using the Extend simulation software. This software allows for a continuous and a discrete-event simulation including hybrid models. Due to the detailed level of modeling, we set up a purely discrete-event model of software

development processes focusing on the stages coding, inspection and module test. For keeping the presentation short, a detailed description of those parts of the model which are not related to modeling software developers are not be included in this paper. Such descriptions together with other simulation results can, however, be found in Neu et al. (2002, 2003)

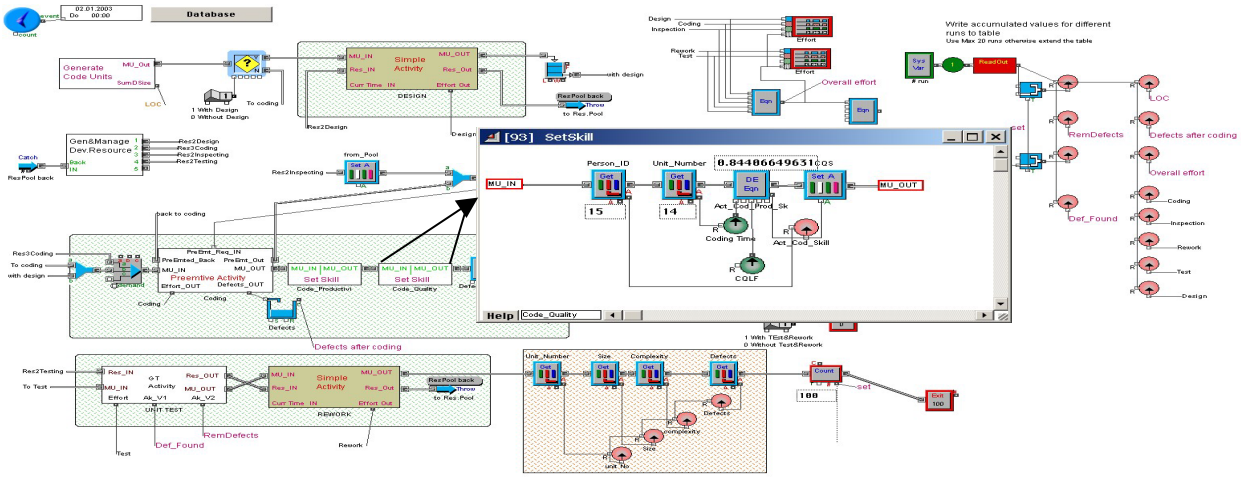

Fig. 8: Excerpt from the graphical interface of our Extend model..

For an experimental investigation on human factors we focused on the effects of starting skills and learning factors. These model parameters have been varied as follows: For the starting skills of each person three different values have been considered: low (0.3), average (0.5), and high (0.7). For the learning factors for coding and inspection, the following settings have been considered for each person: no learning (all learning factors are 0), medium learning speed (coding skills learning factors = 0.0001, inspection skills learning factors = 0.001), and high learning speed (coding skills learning factors = 0.001, inspection skills learning factors = 0.01). The inspection skills learning factor are chosen 10 times higher as those for coding because experimental results showed a comparatively fast learning for these activities.

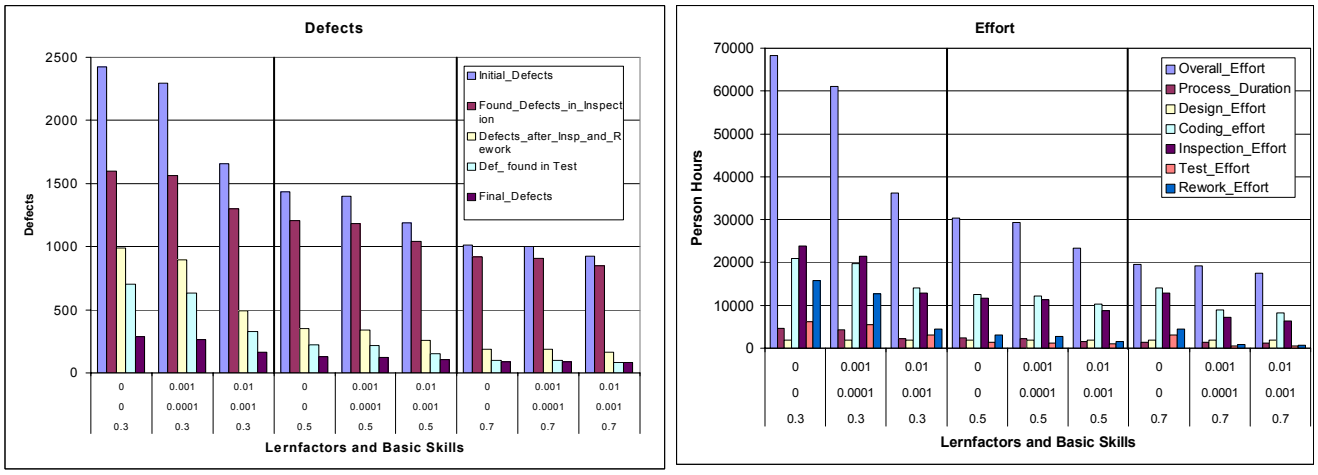

Fig. 9: Model results for varying starting skills and learning factors.

The combination of considered parameter values leads to 9 experimental settings. The average results for the two most interesting outcome variables, effort and defects, are shown in Fig. 9 for ten repeated experiments for each setting. The left diagram shows the number of defects after coding (initial defects), found in inspection, after the rework following the inspection, found during test, and after the final rework (final

defects).The left diagram shows the overall effort, the effort for each of the stages in the process, and its duration. The general tendency of the results is not surprising: The higher the initial skills and the learning factors the better are the results with respect to defects and effort. It is, however, interesting to what extent learning can contribute to the performance of a project. In the case of low initial skills and a high learning rate, it is almost possible to reach the performance of a project with medium initial skills and no learning. Already during the project run, learning enables the developers to a performance above average such that average skill developers are almost gained on. Unfortunately, there are so far few empirical results on the actual learning speed of developers and by which means learning can effectively be facilitated.

6. CONCLUSIONS

In this paper, various human factors influencing productivity in software development processes are considered. As the main factor, learning and effects related to time pressure are discussed. Many other human factors have been neglected up to now. Their impact is considered by stochastic variables that allow, for instance, to perform a series of simulation experiments.

For the future it is planned to refine the models and validate them with empirical data. As discussed in Lang et al. (2003), such data should also allow for determination of complex relationships between influencing and dependent variables, e.g., by tools like neural networks. Unfortunately, up to now, practically no appropriate empirical data on human-based variables has been collected in a systematic way in software developing companies. Validated numerical relationships are also a pre-requisite for reliable optimization of software development processes, see, e.g., Hanne and Nickel (2003).

ACKNOWLEDGEMENTS

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Published reports of the Fraunhofer ITWM

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www.itwm.fraunhofer.de/rd/presse/berichte

1. D. Hietel, K. Steiner, J. Struckmeier

A Finite - Volume Particle Method for Compressible Flows

We derive a new class of particle methods for conservation laws, which are based on numerical flux functions to model the interactions between moving particles. The derivation is similar to that of classical Finite-Volume methods; except that the fixed grid structure in the Finite-Volume method is substituted by so-called mass packets of particles. We give some numerical results on a shock wave solution for Burgers equation as well as the well-known one-dimensional shock tube problem.
(19 pages, 1998)

2. M. Feldmann, S. Seibold

Damage Diagnosis of Rotors: Application of Hilbert Transform and Multi-Hypothesis Testing

In this paper, a combined approach to damage diagnosis of rotors is proposed. The intention is to employ signal-based as well as model-based procedures for an improved detection of size and location of the damage. In a first step, Hilbert transform signal processing techniques allow for a computation of the signal envelope and the instantaneous frequency, so that various types of non-linearities due to a damage may be identified and classified based on measured response data. In a second step, a multi-hypothesis bank of Kalman Filters is employed for the detection of the size and location of the damage based on the information of the type of damage provided by the results of the Hilbert transform.
Keywords: Hilbert transform, damage diagnosis, Kalman filtering, non-linear dynamics
(23 pages, 1998)

3. Y. Ben-Haim, S. Seibold

Robust Reliability of Diagnostic Multi-Hypothesis Algorithms: Application to Rotating Machinery

Damage diagnosis based on a bank of Kalman filters, each one conditioned on a specific hypothesized system condition, is a well recognized and powerful diagnostic tool. This multi-hypothesis approach can be applied to a wide range of damage conditions. In this paper, we will focus on the diagnosis of cracks in rotating machinery. The question we address is: how to optimize the multi-hypothesis algorithm with respect to the uncertainty of the spatial form and location of cracks and their resulting dynamic effects. First, we formulate a measure of the reliability of the diagnostic algorithm, and then we discuss modifications of the diagnostic algorithm for the maximization of the reliability. The reliability of a diagnostic algorithm is measured by the amount of uncertainty consistent with no-failure of the diagnosis. Uncertainty is quantitatively represented with convex models.
Keywords: Robust reliability, convex models, Kalman filtering, multi-hypothesis diagnosis, rotating machinery, crack diagnosis
(24 pages, 1998)

4. F.-Th. Lentes, N. Siedow

Three-dimensional Radiative Heat Transfer in Glass Cooling Processes

For the numerical simulation of 3D radiative heat transfer in glasses and glass melts, practically applicable mathematical methods are needed to handle such problems optimal using workstation class computers. Since the exact solution would require super-computer capabilities we concentrate on approximate solutions with a high degree of accuracy. The following approaches are studied: 3D diffusion approximations and 3D ray-tracing methods.
(23 pages, 1998)

5. A. Klar, R. Wegener

A hierarchy of models for multilane vehicular traffic
Part I: Modeling

In the present paper multilane models for vehicular traffic are considered. A microscopic multilane model based on reaction thresholds is developed. Based on this model an Enskog like kinetic model is developed. In particular, care is taken to incorporate the correlations between the vehicles. From the kinetic model a fluid dynamic model is derived. The macroscopic coefficients are deduced from the underlying kinetic model. Numerical simulations are presented for all three levels of description in [10]. Moreover, a comparison of the results is given there.
(23 pages, 1998)

Part II: Numerical and stochastic investigations

In this paper the work presented in [6] is continued. The present paper contains detailed numerical investigations of the models developed there. A numerical method to treat the kinetic equations obtained in [6] are presented and results of the simulations are shown. Moreover, the stochastic correlation model used in [6] is described and investigated in more detail.
(17 pages, 1998)

6. A. Klar, N. Siedow

Boundary Layers and Domain Decomposition for Radiative Heat Transfer and Diffusion Equations: Applications to Glass Manufacturing Processes

In this paper domain decomposition methods for radiative transfer problems including conductive heat transfer are treated. The paper focuses on semi-transparent materials, like glass, and the associated conditions at the interface between the materials. Using asymptotic analysis we derive conditions for the coupling of the radiative transfer equations and a diffusion approximation. Several test cases are treated and a problem appearing in glass manufacturing processes is computed. The results clearly show the advantages of a domain decomposition approach. Accuracy equivalent to the solution of the global radiative transfer solution is achieved, whereas computation time is strongly reduced.
(24 pages, 1998)

7. I. Choquet

Heterogeneous catalysis modelling and numerical simulation in rarified gas flows Part I: Coverage locally at equilibrium

A new approach is proposed to model and simulate numerically heterogeneous catalysis in rarefied gas flows. It is developed to satisfy all together the following points:
1) describe the gas phase at the microscopic scale, as required in rarefied flows,
2) describe the wall at the macroscopic scale, to avoid prohibitive computational costs and consider not only crystalline but also amorphous surfaces,
3) reproduce on average macroscopic laws correlated with experimental results and
4) derive analytic models in a systematic and exact way. The problem is stated in the general framework of a non static flow in the vicinity of a catalytic and non porous surface (without aging). It is shown that the exact and systematic resolution method based on the Laplace transform, introduced previously by the author to model collisions in the gas phase, can be extended to the present problem. The proposed approach is applied to the modelling of the EleyRideal and LangmuirHinshelwood recombinations, assuming that the coverage is locally at equilibrium. The models are developed considering one atomic species and extended to the general case of several atomic species. Numerical calculations show that the models derived in this way reproduce with accuracy behaviors observed experimentally.
(24 pages, 1998)

8. J. Ohser, B. Steinbach, C. Lang

Efficient Texture Analysis of Binary Images

A new method of determining some characteristics of binary images is proposed based on a special linear filtering. This technique enables the estimation of the area fraction, the specific line length, and the specific integral of curvature. Furthermore, the specific length of the total projection is obtained, which gives detailed information about the texture of the image. The influence of lateral and directional resolution depending on the size of the applied filter mask is discussed in detail. The technique includes a method of increasing directional resolution for texture analysis while keeping lateral resolution as high as possible.
(17 pages, 1998)

9. J. Orlik

Homogenization for viscoelasticity of the integral type with aging and shrinkage

A multiphase composite with periodic distributed inclusions with a smooth boundary is considered in this contribution. The composite component materials are supposed to be linear viscoelastic and aging (of the nonconvolution integral type, for which the Laplace transform with respect to time is not effectively applicable) and are subjected to isotropic shrinkage. The free shrinkage deformation can be considered as a fictitious temperature deformation in the behavior law. The procedure presented in this paper proposes a way to determine average (effective homogenized) viscoelastic and shrinkage (temperature) composite properties and the homogenized stressfield from known properties of the components. This is done by the extension of the asymptotic homogenization technique known for pure elastic nonhomogeneous bodies to the nonhomogeneous thermoviscoelasticity of the integral noncon-

volution type. Up to now, the homogenization theory has not covered viscoelasticity of the integral type. SanchezPalencia (1980), Francfort & Suquet (1987) (see [2], [9]) have considered homogenization for viscoelasticity of the differential form and only up to the first derivative order. The integralmodeled viscoelasticity is more general then the differential one and includes almost all known differential models. The homogenization procedure is based on the construction of an asymptotic solution with respect to a period of the composite structure. This reduces the original problem to some auxiliary boundary value problems of elasticity and viscoelasticity on the unit periodic cell, of the same type as the original non-homogeneous problem. The existence and uniqueness results for such problems were obtained for kernels satisfying some constrain conditions. This is done by the extension of the Volterra integral operator theory to the Volterra operators with respect to the time, whose 1 kernels are space linear operators for any fixed time variables. Some ideas of such approach were proposed in [11] and [12], where the Volterra operators with kernels depending additionally on parameter were considered. This manuscript delivers results of the same nature for the case of the spaceoperator kernels.
(20 pages, 1998)

10. J. Mohring

Helmholtz Resonators with Large Aperture

The lowest resonant frequency of a cavity resonator is usually approximated by the classical Helmholtz formula. However, if the opening is rather large and the front wall is narrow this formula is no longer valid. Here we present a correction which is of third order in the ratio of the diameters of aperture and cavity. In addition to the high accuracy it allows to estimate the damping due to radiation. The result is found by applying the method of matched asymptotic expansions. The correction contains form factors describing the shapes of opening and cavity. They are computed for a number of standard geometries. Results are compared with numerical computations.
(21 pages, 1998)

11. H. W. Hamacher, A. Schöbel

On Center Cycles in Grid Graphs

Finding "good" cycles in graphs is a problem of great interest in graph theory as well as in locational analysis. We show that the center and median problems are NP hard in general graphs. This result holds both for the variable cardinality case (i.e. all cycles of the graph are considered) and the fixed cardinality case (i.e. only cycles with a given cardinality p are feasible). Hence it is of interest to investigate special cases where the problem is solvable in polynomial time. In grid graphs, the variable cardinality case is, for instance, trivially solvable if the shape of the cycle can be chosen freely. If the shape is fixed to be a rectangle one can analyze rectangles in grid graphs with, in sequence, fixed dimension, fixed cardinality, and variable cardinality. In all cases a complete characterization of the optimal cycles and closed form expressions of the optimal objective values are given, yielding polynomial time algorithms for all cases of center rectangle problems. Finally, it is shown that center cycles can be chosen as rectangles for small cardinalities such that the center cycle problem in grid graphs is in these cases completely solved.
(15 pages, 1998)

12. H. W. Hamacher, K.-H. Küfer

Inverse radiation therapy planning - a multiple objective optimisation approach

For some decades radiation therapy has been proved successful in cancer treatment. It is the major task of clinical radiation treatment planning to realize on the one hand a high level dose of radiation in the cancer tissue in order to obtain maximum tumor control. On the other hand it is obvious that it is absolutely necessary to keep in the tissue outside the tumor, particularly in organs at risk, the unavoidable radiation as low as possible.
No doubt, these two objectives of treatment planning - high level dose in the tumor, low radiation outside the tumor - have a basically contradictory nature. Therefore, it is no surprise that inverse mathematical models with dose distribution bounds tend to be infeasible in most cases. Thus, there is need for approximations compromising between overdosing the organs at risk and underdosing the target volume.
Differing from the currently used time consuming iterative approach, which measures deviation from an ideal (non-achievable) treatment plan using recursively trial-and-error weights for the organs of interest, we go a new way trying to avoid a priori weight choices and consider the treatment planning problem as a multiple objective linear programming problem: with each organ of interest, target tissue as well as organs at risk, we associate an objective function measuring the maximal deviation from the prescribed doses.
We build up a data base of relatively few efficient solutions representing and approximating the variety of Pareto solutions of the multiple objective linear programming problem. This data base can be easily scanned by physicians looking for an adequate treatment plan with the aid of an appropriate online tool.
(14 pages, 1999)

13. C. Lang, J. Ohser, R. Hilfer

On the Analysis of Spatial Binary Images

This paper deals with the characterization of microscopically heterogeneous, but macroscopically homogeneous spatial structures. A new method is presented which is strictly based on integral-geometric formulae such as Crofton's intersection formulae and Hadwiger's recursive definition of the Euler number. The corresponding algorithms have clear advantages over other techniques. As an example of application we consider the analysis of spatial digital images produced by means of Computer Assisted Tomography.
(20 pages, 1999)

14. M. Junk

On the Construction of Discrete Equilibrium Distributions for Kinetic Schemes

A general approach to the construction of discrete equilibrium distributions is presented. Such distribution functions can be used to set up Kinetic Schemes as well as Lattice Boltzmann methods. The general principles are also applied to the construction of Chapman Enskog distributions which are used in Kinetic Schemes for compressible Navier-Stokes equations.
(24 pages, 1999)

15. M. Junk, S. V. Raghurame Rao

A new discrete velocity method for Navier-Stokes equations

The relation between the Lattice Boltzmann Method, which has recently become popular, and the Kinetic Schemes, which are routinely used in Computational Fluid Dynamics, is explored. A new discrete velocity model for the numerical solution of Navier-Stokes equations for incompressible fluid flow is presented by combining both the approaches. The new scheme can be interpreted as a pseudo-compressibility method and, for a particular choice of parameters, this interpretation carries over to the Lattice Boltzmann Method.
(20 pages, 1999)

16. H. Neunzert

Mathematics as a Key to Key Technologies

The main part of this paper will consist of examples, how mathematics really helps to solve industrial problems; these examples are taken from our Institute for Industrial Mathematics, from research in the Technomathematics group at my university, but also from ECMI groups and a company called TecMath, which originated 10 years ago from my university group and has already a very successful history.
(39 pages (4 PDF-Files), 1999)

17. J. Ohser, K. Sandau

Considerations about the Estimation of the Size Distribution in Wicksell's Corpuscle Problem

Wicksell's corpuscle problem deals with the estimation of the size distribution of a population of particles, all having the same shape, using a lower dimensional sampling probe. This problem was originary formulated for particle systems occurring in life sciences but its solution is of actual and increasing interest in materials science. From a mathematical point of view, Wicksell's problem is an inverse problem where the interesting size distribution is the unknown part of a Volterra equation. The problem is often regarded ill-posed, because the structure of the integrand implies unstable numerical solutions. The accuracy of the numerical solutions is considered here using the condition number, which allows to compare different numerical methods with different (equidistant) class sizes and which indicates, as one result, that a finite section thickness of the probe reduces the numerical problems. Furthermore, the relative error of estimation is computed which can be split into two parts. One part consists of the relative discretization error that increases for increasing class size, and the second part is related to the relative statistical error which increases with decreasing class size. For both parts, upper bounds can be given and the sum of them indicates an optimal class width depending on some specific constants.
(18 pages, 1999)

18. E. Carrizosa, H. W. Hamacher, R. Klein, S. Nickel

Solving nonconvex planar location problems by finite dominating sets

It is well-known that some of the classical location problems with polyhedral gauges can be solved in polynomial time by finding a finite dominating set, i. e. a finite set of candidates guaranteed to contain at least one optimal location.
In this paper it is first established that this result holds

for a much larger class of problems than currently considered in the literature. The model for which this result can be proven includes, for instance, location problems with attraction and repulsion, and location-allocation problems.
Next, it is shown that the approximation of general gauges by polyhedral ones in the objective function of our general model can be analyzed with regard to the subsequent error in the optimal objective value. For the approximation problem two different approaches are described, the sandwich procedure and the greedy algorithm. Both of these approaches lead - for fixed epsilon - to polynomial approximation algorithms with accuracy epsilon for solving the general model considered in this paper.
Keywords: Continuous Location, Polyhedral Gauges, Finite Dominating Sets, Approximation, Sandwich Algorithm, Greedy Algorithm
(19 pages, 2000)

19. A. Becker

A Review on Image Distortion Measures

Within this paper we review image distortion measures. A distortion measure is a criterion that assigns a "quality number" to an image. We distinguish between mathematical distortion measures and those distortion measures in-cooperating a priori knowledge about the imaging devices (e. g. satellite images), image processing algorithms or the human physiology. We will consider representative examples of different kinds of distortion measures and are going to discuss them.
Keywords: Distortion measure, human visual system
(26 pages, 2000)

20. H. W. Hamacher, M. Labbé, S. Nickel, T. Sonneborn

Polyhedral Properties of the Uncapacitated Multiple Allocation Hub Location Problem

We examine the feasibility polyhedron of the uncapacitated hub location problem (UHL) with multiple allocation, which has applications in the fields of air passenger and cargo transportation, telecommunication and postal delivery services. In particular we determine the dimension and derive some classes of facets of this polyhedron. We develop some general rules about lifting facets from the uncapacitated facility location (UFL) for UHL and projecting facets from UHL to UFL. By applying these rules we get a new class of facets for UHL which dominates the inequalities in the original formulation. Thus we get a new formulation of UHL whose constraints are all facet–defining. We show its superior computational performance by benchmarking it on a well known data set.
Keywords: integer programming, hub location, facility location, valid inequalities, facets, branch and cut
(21 pages, 2000)

21. H. W. Hamacher, A. Schöbel

Design of Zone Tariff Systems in Public Transportation

Given a public transportation system represented by its stops and direct connections between stops, we consider two problems dealing with the prices for the customers: The fare problem in which subsets of stops are already aggregated to zones and "good" tariffs have to be found in the existing zone system. Closed form solutions for the fare problem are presented for three objective functions. In the zone problem the design of the zones is part of the problem. This problem is NP hard and we therefore propose three heuristics which prove to be very successful in the redesign of one of Germany's transportation systems.
(30 pages, 2001)

22. D. Hietel, M. Junk, R. Keck, D. Teleaga:

The Finite-Volume-Particle Method for Conservation Laws

In the Finite-Volume-Particle Method (FVPM), the weak formulation of a hyperbolic conservation law is discretized by restricting it to a discrete set of test functions. In contrast to the usual Finite-Volume approach, the test functions are not taken as characteristic functions of the control volumes in a spatial grid, but are chosen from a partition of unity with smooth and overlapping partition functions (the particles), which can even move along pre- scribed velocity fields. The information exchange between particles is based on standard numerical flux functions. Geometrical information, similar to the surface area of the cell faces in the Finite-Volume Method and the corresponding normal directions are given as integral quantities of the partition functions. After a brief derivation of the Finite-Volume-Particle Method, this work focuses on the role of the geometric coefficients in the scheme.
(16 pages, 2001)

23. T. Bender, H. Hennes, J. Kalcsics, M. T. Melo, S. Nickel

Location Software and Interface with GIS and Supply Chain Management

The objective of this paper is to bridge the gap between location theory and practice. To meet this objective focus is given to the development of software capable of addressing the different needs of a wide group of users. There is a very active community on location theory encompassing many research fields such as operations research, computer science, mathematics, engineering, geography, economics and marketing. As a result, people working on facility location problems have a very diverse background and also different needs regarding the software to solve these problems. For those interested in non-commercial applications (e. g. students and researchers), the library of location algorithms (LoLA can be of considerable assistance. LoLA contains a collection of efficient algorithms for solving planar, network and discrete facility location problems. In this paper, a detailed description of the functionality of LoLA is presented. In the fields of geography and marketing, for instance, solving facility location problems requires using large amounts of demographic data. Hence, members of these groups (e. g. urban planners and sales managers) often work with geographical information too s. To address the specific needs of these users, LoLA was inked to a geographical information system (GIS) and the details of the combined functionality are described in the paper. Finally, there is a wide group of practitioners who need to solve large problems and require special purpose software with a good data interface. Many of such users can be found, for example, in the area of supply chain management (SCM). Logistics activities involved in strategic SCM include, among others, facility location planning. In this paper, the development of a commercial location software tool is also described. The too is embedded in the Advanced Planner and Optimizer SCM software developed by SAP AG, Walldorf, Germany. The paper ends with some conclusions and an outlook to future activities.
Keywords: facility location, software development, geographical information systems, supply chain management.
(48 pages, 2001)

24. H. W. Hamacher, S. A. Tjandra

Mathematical Modelling of Evacuation Problems: A State of Art

This paper details models and algorithms which can be applied to evacuation problems. While it concentrates on building evacuation many of the results are applicable also to regional evacuation. All models consider the time as main parameter, where the travel time between components of the building is part of the input and the overall evacuation time is the output. The paper distinguishes between macroscopic and microscopic evacuation models both of which are able to capture the evacuees' movement over time.
Macroscopic models are mainly used to produce good lower bounds for the evacuation time and do not consider any individual behavior during the emergency situation. These bounds can be used to analyze existing buildings or help in the design phase of planning a building. Macroscopic approaches which are based on dynamic network flow models (minimum cost dynamic flow, maximum dynamic flow, universal maximum flow, quickest path and quickest flow) are described. A special feature of the presented approach is the fact, that travel times of evacuees are not restricted to be constant, but may be density dependent. Using multicriteria optimization priority regions and blockage due to fire or smoke may be considered. It is shown how the modelling can be done using time parameter either as discrete or continuous parameter.
Microscopic models are able to model the individual evacuee's characteristics and the interaction among evacuees which influence their movement. Due to the corresponding huge amount of data one uses simulation approaches. Some probabilistic laws for individual evacuee's movement are presented. Moreover ideas to model the evacuee's movement using cellular automata (CA) and resulting software are presented. In this paper we will focus on macroscopic models and only summarize some of the results of the microscopic approach. While most of the results are applicable to general evacuation situations, we concentrate on building evacuation.
(44 pages, 2001)

25. J. Kuhnert, S. Tiwari

Grid free method for solving the Poisson equation

A Grid free method for solving the Poisson equation is presented. This is an iterative method. The method is based on the weighted least squares approximation in which the Poisson equation is enforced to be satisfied in every iterations. The boundary conditions can also be enforced in the iteration process. This is a local approximation procedure. The Dirichlet, Neumann and mixed boundary value problems on a unit square are presented and the analytical solutions are compared with the exact solutions. Both solutions matched perfectly.
Keywords: Poisson equation, Least squares method, Grid free method
(19 pages, 2001)

26. T. Götz, H. Rave, D. Reinel-Bitzer, K. Steiner, H. Tiemeier

Simulation of the fiber spinning process

To simulate the influence of process parameters to the melt spinning process a fiber model is used and coupled with CFD calculations of the quench air flow. In the fiber model energy, momentum and mass balance are solved for the polymer mass flow. To calculate the quench air the Lattice Boltzmann method is used. Simulations and experiments for different process parameters and hole configurations are compared and show a good agreement.

Keywords: Melt spinning, fiber model, Lattice Boltzmann, CFD

(19 pages, 2001)

27. A. Zemitis

On interaction of a liquid film with an obstacle

In this paper mathematical models for liquid films generated by impinging jets are discussed. Attention is stressed to the interaction of the liquid film with some obstacle. S. G. Taylor [Proc. R. Soc. London Ser. A 253, 313 (1959)] found that the liquid film generated by impinging jets is very sensitive to properties of the wire which was used as an obstacle. The aim of this presentation is to propose a modification of the Taylor's model, which allows to simulate the film shape in cases, when the angle between jets is different from 180°. Numerical results obtained by discussed models give two different shapes of the liquid film similar as in Taylors experiments. These two shapes depend on the regime: either droplets are produced close to the obstacle or not. The difference between two regimes becomes larger if the angle between jets decreases. Existence of such two regimes can be very essential for some applications of impinging jets, if the generated liquid film can have a contact with obstacles.

Keywords: impinging jets, liquid film, models, numerical solution, shape

(22 pages, 2001)

28. I. Ginzburg, K. Steiner

Free surface lattice-Boltzmann method to model the filling of expanding cavities by Bingham Fluids

The filling process of viscoplastic metal alloys and plastics in expanding cavities is modelled using the lattice Boltzmann method in two and three dimensions. These models combine the regularized Bingham model for viscoplastic with a free-interface algorithm. The latter is based on a modified immiscible lattice Boltzmann model in which one species is the fluid and the other one is considered as vacuum. The boundary conditions at the curved liquid-vacuum interface are met without any geometrical front reconstruction from a first-order Chapman-Enskog expansion. The numerical results obtained with these models are found in good agreement with available theoretical and numerical analysis.

Keywords: Generalized LBE, free-surface phenomena, interface boundary conditions, filling processes, Bingham viscoplastic model, regularized models

(22 pages, 2001)

29. H. Neunzert

»Denn nichts ist für den Menschen als Menschen etwas wert, was er nicht mit Leidenschaft tun kann«

Vortrag anlässlich der Verleihung des Akademiepreises des Landes Rheinland-Pfalz am 21.11.2001

Was macht einen guten Hochschullehrer aus? Auf diese Frage gibt es sicher viele verschiedene, fachbezogene Antworten, aber auch ein paar allgemeine Gesichtspunkte: es bedarf der »Leidenschaft« für die Forschung (Max Weber), aus der dann auch die Begeisterung für die Lehre erwächst. Forschung und Lehre gehören zusammen, um die Wissenschaft als lebendiges Tun vermitteln zu können. Der Vortrag gibt Beispiele dafür, wie in angewandter Mathematik Forschungsaufgaben aus praktischen Alltagsproblemstellungen erwachsen, die in die Lehre auf verschiedenen Stufen (Gymnasium bis Graduiertenkolleg) einfließen; er leitet damit auch zu einem aktuellen Forschungsgebiet, der Mehrskalenanalyse mit ihren vielfältigen Anwendungen in Bildverarbeitung, Materialentwicklung und Strömungsmechanik über, was aber nur kurz gestreift wird. Mathematik erscheint hier als eine moderne Schlüsseltechnologie, die aber auch enge Beziehungen zu den Geistes- und Sozialwissenschaften hat.

Keywords: Lehre, Forschung, angewandte Mathematik, Mehrskalenanalyse, Strömungsmechanik

(18 pages, 2001)

30. J. Kuhnert, S. Tiwari

Finite pointset method based on the projection method for simulations of the incompressible Navier-Stokes equations

A Lagrangian particle scheme is applied to the projection method for the incompressible Navier-Stokes equations. The approximation of spatial derivatives is obtained by the weighted least squares method. The pressure Poisson equation is solved by a local iterative procedure with the help of the least squares method. Numerical tests are performed for two dimensional cases. The Couette flow, Poiseuelle flow, decaying shear flow and the driven cavity flow are presented. The numerical solutions are obtained for stationary as well as instationary cases and are compared with the analytical solutions for channel flows. Finally, the driven cavity in a unit square is considered and the stationary solution obtained from this scheme is compared with that from the finite element method.

Keywords: Incompressible Navier-Stokes equations, Meshfree method, Projection method, Particle scheme, Least squares approximation

AMS subject classification: 76D05, 76M28

(25 pages, 2001)

31. R. Korn, M. Krekel

Optimal Portfolios with Fixed Consumption or Income Streams

We consider some portfolio optimisation problems where either the investor has a desire for an a priori specified consumption stream or/and follows a deterministic pay in scheme while also trying to maximize expected utility from final wealth. We derive explicit closed form solutions for continuous and discrete monetary streams. The mathematical method used is classical stochastic control theory.

Keywords: Portfolio optimisation, stochastic control, HJB equation, discretisation of control problems.

(23 pages, 2002)

32. M. Krekel

Optimal portfolios with a loan dependent credit spread

If an investor borrows money he generally has to pay higher interest rates than he would have received, if he had put his funds on a savings account. The classical model of continuous time portfolio optimisation ignores this effect. Since there is obviously a connection between the default probability and the total percentage of wealth, which the investor is in debt, we study portfolio optimisation with a control dependent interest rate. Assuming a logarithmic and a power utility function, respectively, we prove explicit formulae of the optimal control.

Keywords: Portfolio optimisation, stochastic control, HJB equation, credit spread, log utility, power utility, non-linear wealth dynamics

(25 pages, 2002)

33. J. Ohser, W. Nagel, K. Schladitz

The Euler number of discretized sets - on the choice of adjacency in homogeneous lattices

Two approaches for determining the Euler-Poincaré characteristic of a set observed on lattice points are considered in the context of image analysis { the integral geometric and the polyhedral approach. Information about the set is assumed to be available on lattice points only. In order to retain properties of the Euler number and to provide a good approximation of the true Euler number of the original set in the Euclidean space, the appropriate choice of adjacency in the lattice for the set and its background is crucial. Adjacencies are defined using tessellations of the whole space into polyhedrons. In R 3 , two new 14 adjacencies are introduced additionally to the well known 6 and 26 adjacencies. For the Euler number of a set and its complement, a consistency relation holds. Each of the pairs of adjacencies (14:1; 14:1), (14:2; 14:2), (6; 26), and (26; 6) is shown to be a pair of complementary adjacencies with respect to this relation. That is, the approximations of the Euler numbers are consistent if the set and its background (complement) are equipped with this pair of adjacencies. Furthermore, sufficient conditions for the correctness of the approximations of the Euler number are given. The analysis of selected microstructures and a simulation study illustrate how the estimated Euler number depends on the chosen adjacency. It also shows that there is not a uniquely best pair of adjacencies with respect to the estimation of the Euler number of a set in Euclidean space.

Keywords: image analysis, Euler number, neighborhod relationships, cuboidal lattice

(32 pages, 2002)

34. I. Ginzburg, K. Steiner

Lattice Boltzmann Model for Free-Surface flow and Its Application to Filling Process in Casting

A generalized lattice Boltzmann model to simulate free-surface is constructed in both two and three dimensions. The proposed model satisfies the interfacial boundary conditions accurately. A distinctive feature of the model is that the collision processes is carried out only on the points occupied partially or fully by the fluid. To maintain a sharp interfacial front, the method

includes an anti-diffusion algorithm. The unknown distribution functions at the interfacial region are constructed according to the first order Chapman-Enskog analysis. The interfacial boundary conditions are satisfied exactly by the coefficients in the Chapman-Enskog expansion. The distribution functions are naturally expressed in the local interfacial coordinates. The macroscopic quantities at the interface are extracted from the least-square solutions of a locally linearized system obtained from the known distribution functions. The proposed method does not require any geometric front construction and is robust for any interfacial topology. Simulation results of realistic filling process are presented: rectangular cavity in two dimensions and Hammer box, Campbell box, Sheffield box, and Motorblock in three dimensions. To enhance the stability at high Reynolds numbers, various upwind-type schemes are developed. Free-slip and no-slip boundary conditions are also discussed.
Keywords: Lattice Boltzmann models; free-surface phenomena; interface boundary conditions; filling processes; injection molding; volume of fluid method; interface boundary conditions; advection-schemes; upwind-schemes
(54 pages, 2002)

35. M. Günther, A. Klar, T. Materne, R. Wegener

Multivalued fundamental diagrams and stop and go waves for continuum traffic equations

In the present paper a kinetic model for vehicular traffic leading to multivalued fundamental diagrams is developed and investigated in detail. For this model phase transitions can appear depending on the local density and velocity of the flow. A derivation of associated macroscopic traffic equations from the kinetic equation is given. Moreover, numerical experiments show the appearance of stop and go waves for highway traffic with a bottleneck.
Keywords: traffic flow, macroscopic equations, kinetic derivation, multivalued fundamental diagram, stop and go waves, phase transitions
(25 pages, 2002)

36. S. Feldmann, P. Lang, D. Prätzel-Wolters

Parameter influence on the zeros of network determinants

To a network N(q) with determinant D(s;q) depending on a parameter vector $q \in R^r$ via identification of some of its vertices, a network N^ (q) is assigned. The paper deals with procedures to find N^ (q), such that its determinant D^ (s;q) admits a factorization in the determinants of appropriate subnetworks, and with the estimation of the deviation of the zeros of D^ from the zeros of D. To solve the estimation problem state space methods are applied.
Keywords: Networks, Equicofactor matrix polynomials, Realization theory, Matrix perturbation theory
(30 pages, 2002)

37. K. Koch, J. Ohser, K. Schladitz

Spectral theory for random closed sets and estimating the covariance via frequency space

A spectral theory for stationary random closed sets is developed and provided with a sound mathematical basis. Definition and proof of existence of the Bartlett spectrum of a stationary random closed set as well as the proof of a Wiener-Khintchine theorem for the power spectrum are used to two ends: First, well known second order characteristics like the covariance can be estimated faster than usual via frequency space. Second, the Bartlett spectrum and the power spectrum can be used as second order characteristics in frequency space. Examples show, that in some cases information about the random closed set is easier to obtain from these characteristics in frequency space than from their real world counterparts.
Keywords: Random set, Bartlett spectrum, fast Fourier transform, power spectrum
(28 pages, 2002)

38. D. d'Humières, I. Ginzburg

Multi-reflection boundary conditions for lattice Boltzmann models

We present a unified approach of several boundary conditions for lattice Boltzmann models. Its general framework is a generalization of previously introduced schemes such as the bounce-back rule, linear or quadratic interpolations, etc. The objectives are two fold: first to give theoretical tools to study the existing boundary conditions and their corresponding accuracy; secondly to design formally third- order accurate boundary conditions for general flows. Using these boundary conditions, Couette and Poiseuille flows are exact solution of the lattice Boltzmann models for a Reynolds number $Re = 0$ (Stokes limit).
Numerical comparisons are given for Stokes flows in periodic arrays of spheres and cylinders, linear periodic array of cylinders between moving plates and for Navier-Stokes flows in periodic arrays of cylinders for $Re < 200$. These results show a significant improvement of the overall accuracy when using the linear interpolations instead of the bounce-back reflection (up to an order of magnitude on the hydrodynamics fields). Further improvement is achieved with the new multi-reflection boundary conditions, reaching a level of accuracy close to the quasi-analytical reference solutions, even for rather modest grid resolutions and few points in the narrowest channels. More important, the pressure and velocity fields in the vicinity of the obstacles are much smoother with multi-reflection than with the other boundary conditions.
Finally the good stability of these schemes is highlighted by some simulations of moving obstacles: a cylinder between flat walls and a sphere in a cylinder.
Keywords: lattice Boltzmann equation, boudary condistions, bounce-back rule, Navier-Stokes equation
(72 pages, 2002)

39. R. Korn

Elementare Finanzmathematik

Im Rahmen dieser Arbeit soll eine elementar gehaltene Einführung in die Aufgabenstellungen und Prinzipien der modernen Finanzmathematik gegeben werden. Insbesondere werden die Grundlagen der Modellierung von Aktienkursen, der Bewertung von Optionen und der Portfolio-Optimierung vorgestellt. Natürlich können die verwendeten Methoden und die entwickelte Theorie nicht in voller Allgemeinheit für den Schulunterricht verwendet werden, doch sollen einzelne Prinzipien so heraus gearbeitet werden, dass sie auch an einfachen Beispielen verstanden werden können.
Keywords: Finanzmathematik, Aktien, Optionen, Portfolio-Optimierung, Börse, Lehrerweiterbildung, Mathematikunterricht
(98 pages, 2002)

40. J. Kallrath, M. C. Müller, S. Nickel

Batch Presorting Problems: Models and Complexity Results

In this paper we consider short term storage systems. We analyze presorting strategies to improve the effiency of these storage systems. The presorting task is called Batch PreSorting Problem (BPSP). The BPSP is a variation of an assigment problem, i. e., it has an assigment problem kernel and some additional constraints. We present different types of these presorting problems, introduce mathematical programming formulations and prove the NP-completeness for one type of the BPSP. Experiments are carried out in order to compare the different model formulations and to investigate the behavior of these models.
Keywords: Complexity theory, Integer programming, Assigment, Logistics
(19 pages, 2002)

41. J. Linn

On the frame-invariant description of the phase space of the Folgar-Tucker equation

The Folgar-Tucker equation is used in flow simulations of fiber suspensions to predict fiber orientation depending on the local flow. In this paper, a complete, frame-invariant description of the phase space of this differential equation is presented for the first time.
Key words: fiber orientation, Folgar-Tucker equation, injection molding
(5 pages, 2003)

42. T. Hanne, S. Nickel

A Multi-Objective Evolutionary Algorithm for Scheduling and Inspection Planning in Software Development Projects

In this article, we consider the problem of planning inspections and other tasks within a software development (SD) project with respect to the objectives quality (no. of defects), project duration, and costs. Based on a discrete-event simulation model of SD processes comprising the phases coding, inspection, test, and rework, we present a simplified formulation of the problem as a multiobjective optimization problem. For solving the problem (i. e. finding an approximation of the efficient set) we develop a multiobjective evolutionary algorithm. Details of the algorithm are discussed as well as results of its application to sample problems.
Key words: multiple objective programming, project management and scheduling, software development, evolutionary algorithms, efficient set
(29 pages, 2003)

43. T. Bortfeld , K.-H. Küfer, M. Monz, A. Scherrer, C. Thieke, H. Trinkaus

Intensity-Modulated Radiotherapy - A Large Scale Multi-Criteria Programming Problem -

Radiation therapy planning is always a tight rope walk between dangerous insufficient dose in the target volume and life threatening overdosing of organs at

risk. Finding ideal balances between these inherently contradictory goals challenges dosimetrists and physicians in their daily practice. Today's planning systems are typically based on a single evaluation function that measures the quality of a radiation treatment plan. Unfortunately, such a one dimensional approach cannot satisfactorily map the different backgrounds of physicians and the patient dependent necessities. So, too often a time consuming iteration process between evaluation of dose distribution and redefinition of the evaluation function is needed.
In this paper we propose a generic multi-criteria approach based on Pareto's solution concept. For each entity of interest - target volume or organ at risk a structure dependent evaluation function is defined measuring deviations from ideal doses that are calculated from statistical functions. A reasonable bunch of clinically meaningful Pareto optimal solutions are stored in a data base, which can be interactively searched by physicians. The system guarantees dynamical planning as well as the discussion of tradeoffs between different entities.
Mathematically, we model the upcoming inverse problem as a multi-criteria linear programming problem. Because of the large scale nature of the problem it is not possible to solve the problem in a 3D-setting without adaptive reduction by appropriate approximation schemes.
Our approach is twofold: First, the discretization of the continuous problem is based on an adaptive hierarchical clustering process which is used for a local refinement of constraints during the optimization procedure. Second, the set of Pareto optimal solutions is approximated by an adaptive grid of representatives that are found by a hybrid process of calculating extreme compromises and interpolation methods.
Keywords: multiple criteria optimization, representative systems of Pareto solutions, adaptive triangulation, clustering and disaggregation techniques, visualization of Pareto solutions, medical physics, external beam radiotherapy planning, intensity modulated radiotherapy
(31 pages, 2003)

44. T. Halfmann, T. Wichmann

Overview of Symbolic Methods in Industrial Analog Circuit Design

Industrial analog circuits are usually designed using numerical simulation tools. To obtain a deeper circuit understanding, symbolic analysis techniques can additionally be applied. Approximation methods which reduce the complexity of symbolic expressions are needed in order to handle industrial-sized problems. This paper will give an overview to the field of symbolic analog circuit analysis. Starting with a motivation, the state-of-the-art simplification algorithms for linear as well as for nonlinear circuits are presented. The basic ideas behind the different techniques are described, whereas the technical details can be found in the cited references. Finally, the application of linear and nonlinear symbolic analysis will be shown on two example circuits.
Keywords: CAD, automated analog circuit design, symbolic analysis, computer algebra, behavioral modeling, system simulation, circuit sizing, macro modeling, differential-algebraic equations, index
(17 pages, 2003)

45. S. E. Mikhailov, J. Orlik

Asymptotic Homogenisation in Strength and Fatigue Durability Analysis of Composites

Asymptotic homogenisation technique and two-scale convergence is used for analysis of macro-strength and fatigue durability of composites with a periodic structure under cyclic loading. The linear damage accumulation rule is employed in the phenomenological micro-durability conditions (for each component of the composite) under varying cyclic loading. Both local and non-local strength and durability conditions are analysed. The strong convergence of the strength and fatigue damage measure as the structure period tends to zero is proved and their limiting values are estimated.
Keywords: multiscale structures, asymptotic homogenization, strength, fatigue, singularity, non-local conditions
(14 pages, 2003)

46. P. Domínguez-Marín, P. Hansen, N. Mladenović, S. Nickel

Heuristic Procedures for Solving the Discrete Ordered Median Problem

We present two heuristic methods for solving the Discrete Ordered Median Problem (DOMP), for which no such approaches have been developed so far. The DOMP generalizes classical discrete facility location problems, such as the p-median, p-center and Uncapacitated Facility Location problems. The first procedure proposed in this paper is based on a genetic algorithm developed by Moreno Vega [MV96] for p-median and p-center problems. Additionally, a second heuristic approach based on the Variable Neighborhood Search metaheuristic (VNS) proposed by Hansen & Mladenovic [HM97] for the p-median problem is described. An extensive numerical study is presented to show the efficiency of both heuristics and compare them.
Keywords: genetic algorithms, variable neighborhood search, discrete facility location
(31 pages, 2003)

47. N. Boland, P. Domínguez-Marín, S. Nickel, J. Puerto

Exact Procedures for Solving the Discrete Ordered Median Problem

The Discrete Ordered Median Problem (DOMP) generalizes classical discrete location problems, such as the N-median, N-center and Uncapacitated Facility Location problems. It was introduced by Nickel [16], who formulated it as both a nonlinear and a linear integer program. We propose an alternative integer linear programming formulation for the DOMP, discuss relationships between both integer linear programming formulations, and show how properties of optimal solutions can be used to strengthen these formulations. Moreover, we present a specific branch and bound procedure to solve the DOMP more efficiently. We test the integer linear programming formulations and this branch and bound method computationally on randomly generated test problems.
Keywords: discrete location, Integer programming
(41 pages, 2003)

48. S. Feldmann, P. Lang

Padé-like reduction of stable discrete linear systems preserving their stability

A new stability preserving model reduction algorithm for discrete linear SISO-systems based on their impulse response is proposed. Similar to the Padé approximation, an equation system for the Markov parameters involving the Hankel matrix is considered, that here however is chosen to be of very high dimension. Although this equation system therefore in general cannot be solved exactly, it is proved that the approximate solution, computed via the Moore-Penrose inverse, gives rise to a stability preserving reduction scheme, a property that cannot be guaranteed for the Padé approach. Furthermore, the proposed algorithm is compared to another stability preserving reduction approach, namely the balanced truncation method, showing comparable performance of the reduced systems. The balanced truncation method however starts from a state space description of the systems and in general is expected to be more computational demanding.
Keywords: Discrete linear systems, model reduction, stability, Hankel matrix, Stein equation
(16 pages, 2003)

49. J. Kallrath, S. Nickel

A Polynomial Case of the Batch Presorting Problem

This paper presents new theoretical results for a special case of the batch presorting problem (BPSP). We will show tht this case can be solved in polynomial time. Offline and online algorithms are presented for solving the BPSP. Competetive analysis is used for comparing the algorithms.
Keywords: batch presorting problem, online optimization, competetive analysis, polynomial algorithms, logistics
(17 pages, 2003)

50. T. Hanne, H. L. Trinkaus

knowCube for MCDM – Visual and Interactive Support for Multicriteria Decision Making

In this paper, we present a novel multicriteria decision support system (MCDSS), called knowCube, consisting of components for knowledge organization, generation, and navigation. Knowledge organization rests upon a database for managing qualitative and quantitative criteria, together with add-on information. Knowledge generation serves filling the database via e. g. identification, optimization, classification or simulation. For "finding needles in haycocks", the knowledge navigation component supports graphical database retrieval and interactive, goal-oriented problem solving. Navigation "helpers" are, for instance, cascading criteria aggregations, modifiable metrics, ergonomic interfaces, and customizable visualizations. Examples from real-life projects, e.g. in industrial engineering and in the life sciences, illustrate the application of our MCDSS.
Key words: Multicriteria decision making, knowledge management, decision support systems, visual interfaces, interactive navigation, real-life applications.
(26 pages, 2003)

51. O. Iliev, V. Laptev

On Numerical Simulation of Flow Through Oil Filters

This paper concerns numerical simulation of flow through oil filters. Oil filters consist of filter housing (filter box), and a porous filtering medium, which completely separates the inlet from the outlet. We discuss mathematical models, describing coupled flows in the

pure liquid subregions and in the porous filter media, as well as interface conditions between them. Further, we reformulate the problem in fictitious regions method manner, and discuss peculiarities of the numerical algorithm in solving the coupled system. Next, we show numerical results, validating the model and the algorithm. Finally, we present results from simulation of 3-D oil flow through a real car filter.
Keywords: oil filters, coupled flow in plain and porous media, Navier-Stokes, Brinkman, numerical simulation
(8 pages, 2003)

52. W. Dörfler, O. Iliev, D. Stoyanov, D. Vassileva

On a Multigrid Adaptive Refinement Solver for Saturated Non-Newtonian Flow in Porous Media

A multigrid adaptive refinement algorithm for non-Newtonian flow in porous media is presented. The saturated flow of a non-Newtonian fluid is described by the continuity equation and the generalized Darcy law. The resulting second order nonlinear elliptic equation is discretized by a finite volume method on a cell-centered grid. A nonlinear full-multigrid, full-approximation-storage algorithm is implemented. As a smoother, a single grid solver based on Picard linearization and Gauss-Seidel relaxation is used. Further, a local refinement multigrid algorithm on a composite grid is developed. A residual based error indicator is used in the adaptive refinement criterion. A special implementation approach is used, which allows us to perform unstructured local refinement in conjunction with the finite volume discretization. Several results from numerical experiments are presented in order to examine the performance of the solver.
Keywords: Nonlinear multigrid, adaptive refinement, non-Newtonian flow in porous media
(17 pages, 2003)

53. S. Kruse

On the Pricing of Forward Starting Options under Stochastic Volatility

We consider the problem of pricing European forward starting options in the presence of stochastic volatility. By performing a change of measure using the asset price at the time of strike determination as a numeraire, we derive a closed-form solution based on Heston's model of stochastic volatility.
Keywords: Option pricing, forward starting options, Heston model, stochastic volatility, cliquet options
(11 pages, 2003)

54. O. Iliev, D. Stoyanov

Multigrid – adaptive local refinement solver for incompressible flows

A non-linear multigrid solver for incompressible Navier-Stokes equations, exploiting finite volume discretization of the equations, is extended by adaptive local refinement. The multigrid is the outer iterative cycle, while the SIMPLE algorithm is used as a smoothing procedure. Error indicators are used to define the refinement subdomain. A special implementation approach is used, which allows to perform unstructured local refinement in conjunction with the finite volume discretization. The multigrid - adaptive local refinement algorithm is tested on 2D Poisson equation and further is applied to a lid-driven flows in a cavity (2D and 3D case), comparing the results with bench-mark data. The software design principles of the solver are also discussed.
Keywords: Navier-Stokes equations, incompressible flow, projection-type splitting, SIMPLE, multigrid methods, adaptive local refinement, lid-driven flow in a cavity
(37 pages, 2003)

55. V. Starikovicius

The multiphase flow and heat transfer in porous media

In first part of this work, summaries of traditional Multiphase Flow Model and more recent Multiphase Mixture Model are presented. Attention is being paid to attempts include various heterogeneous aspects into models. In second part, MMM based differential model for two-phase immiscible flow in porous media is considered. A numerical scheme based on the sequential solution procedure and control volume based finite difference schemes for the pressure and saturation-conservation equations is developed. A computer simulator is built, which exploits object-oriented programming techniques. Numerical result for several test problems are reported.
Keywords: Two-phase flow in porous media, various formulations, global pressure, multiphase mixture model, numerical simulation
(30 pages, 2003)

56. P. Lang, A. Sarishvili, A. Wirsen

Blocked neural networks for knowledge extraction in the software development process

One of the main goals of an organization developing software is to increase the quality of the software while at the same time to decrease the costs and the duration of the development process. To achieve this, various decisions e.ecting this goal before and during the development process have to be made by the managers. One appropriate tool for decision support are simulation models of the software life cycle, which also help to understand the dynamics of the software development process. Building up a simulation model requires a mathematical description of the interactions between di.erent objects involved in the development process. Based on experimental data, techniques from the .eld of knowledge discovery can be used to quantify these interactions and to generate new process knowledge based on the analysis of the determined relationships. In this paper blocked neuronal networks and related relevance measures will be presented as an appropriate tool for quanti.cation and validation of qualitatively known dependencies in the software development process.
Keywords: Blocked Neural Networks, Nonlinear Regression, Knowledge Extraction, Code Inspection
(21 pages, 2003)

57. H. Knaf, P. Lang, S. Zeiser

Diagnosis aiding in Regulation Thermography using Fuzzy Logic

The objective of the present article is to give an overview of an application of Fuzzy Logic in Regulation Thermography, a method of medical diagnosis support. An introduction to this method of the complementary medical science based on temperature measurements – so-called thermograms – is provided. The process of modelling the physician's thermogram evaluation rules using the calculus of Fuzzy Logic is explained.
Keywords: fuzzy logic,knowledge representation, expert system
(22 pages, 2003)

58. M.T. Melo, S. Nickel, F. Saldanha da Gama

Largescale models for dynamic multi-commodity capacitated facility location

In this paper we focus on the strategic design of supply chain networks. We propose a mathematical modeling framework that captures many practical aspects of network design problems simultaneously but which have not received adequate attention in the literature. The aspects considered include: dynamic planning horizon, generic supply chain network structure, external supply of materials, inventory opportunities for goods, distribution of commodities, facility configuration, availability of capital for investments, and storage limitations. Moreover, network configuration decisions concerning the gradual relocation of facilities over the planning horizon are considered. To cope with fluctuating demands, capacity expansion and reduction scenarios are also analyzed as well as modular capacity shifts. The relation of the proposed modeling framework with existing models is discussed. For problems of reasonable size we report on our computational experience with standard mathematical programming software. In particular, useful insights on the impact of various factors on network design decisions are provided.
Keywords: supply chain management, strategic planning, dynamic location, modeling
(40 pages, 2003)

59. J. Orlik

Homogenization for contact problems with periodically rough surfaces

We consider the contact of two elastic bodies with rough surfaces at the interface. The size of the micropeaks and valleys is very small compared with the macrosize of the bodies' domains. This makes the direct application of the FEM for the calculation of the contact problem prohibitively costly. A method is developed that allows deriving a macrocontact condition on the interface. The method involves the twoscale asymptotic homogenization procedure that takes into account the microgeometry of the interface layer and the stiffnesses of materials of both domains. The macrocontact condition can then be used in a FEM model for the contact problem on the macrolevel. The averaged contact stiffness obtained allows the replacement of the interface layer in the macromodel by the macrocontact condition.
Keywords: asymptotic homogenization, contact problems
(28 pages, 2004)

60. A. Scherrer, K.-H. Küfer, M. Monz, F. Alonso, T. Bortfeld

IMRT planning on adaptive volume structures – a significant advance of computational complexity

In intensity-modulated radiotherapy (IMRT) planning the oncologist faces the challenging task of finding a treatment plan that he considers to be an ideal compromise of the inherently contradictive goals of delivering a sufficiently high dose to the target while widely sparing critical structures. The search for this a priori unknown compromise typically requires the computation of several plans, i.e. the solution of several optimization problems. This accumulates to a high computational expense due to the large scale of these problems - a consequence of the discrete problem formulation. This paper presents the adaptive clustering method as a new algorithmic concept to overcome these difficulties. The computations are performed on an individually adapted structure of voxel clusters rather than on the original voxels leading to a decisively reduced computational complexity as numerical examples on real clinical data demonstrate. In contrast to many other similar concepts, the typical trade-off between a reduction in computational complexity and a loss in exactness can be avoided: the adaptive clustering method produces the optimum of the original problem. This flexible method can be applied to both single- and multi-criteria optimization methods based on most of the convex evaluation functions used in practice.
Keywords: Intensity-modulated radiation therapy (IMRT), inverse treatment planning, adaptive volume structures, hierarchical clustering, local refinement, adaptive clustering, convex programming, mesh generation, multi-grid methods
(24 pages, 2004)

61. D. Kehrwald

Parallel lattice Boltzmann simulation of complex flows

After a short introduction to the basic ideas of lattice Boltzmann methods and a brief description of a modern parallel computer, it is shown how lattice Boltzmann schemes are successfully applied for simulating fluid flow in microstructures and calculating material properties of porous media. It is explained how lattice Boltzmann schemes compute the gradient of the velocity field without numerical differentiation. This feature is then utilised for the simulation of pseudo-plastic fluids, and numerical results are presented for a simple benchmark problem as well as for the simulation of liquid composite moulding.
Keywords: Lattice Boltzmann methods, parallel computing, microstructure simulation, virtual material design, pseudo-plastic fluids, liquid composite moulding
(12 pages, 2004)

62. O. Iliev, J. Linn, M. Moog, D. Niedziela, V. Starikovicius

On the Performance of Certain Iterative Solvers for Coupled Systems Arising in Discretization of Non-Newtonian Flow Equations

Iterative solution of large scale systems arising after discretization and linearization of the unsteady non-Newtonian Navier–Stokes equations is studied. cross WLF model is used to account for the non-Newtonian behavior of the fluid. Finite volume method is used to discretize the governing system of PDEs. Viscosity is treated explicitely (e.g., it is taken from the previous time step), while other terms are treated implicitly. Different preconditioners (block–diagonal, block–triangular, relaxed incomplete LU factorization, etc.) are used in conjunction with advanced iterative methods, namely, BiCGStab, CGS, GMRES. The action of the preconditioner in fact requires inverting different blocks. For this purpose, in addition to preconditioned BiCGStab, CGS, GMRES, we use also algebraic multigrid method (AMG). The performance of the iterative solvers is studied with respect to the number of unknowns, characteristic velocity in the basic flow, time step, deviation from Newtonian behavior, etc. Results from numerical experiments are presented and discussed.
Keywords: Performance of iterative solvers, Preconditioners, Non-Newtonian flow
(17 pages, 2004)

63. R. Ciegis, O. Iliev, S. Rief, K. Steiner

On Modelling and Simulation of Different Regimes for Liquid Polymer Moulding

In this paper we consider numerical algorithms for solving a system of nonlinear PDEs arising in modeling of liquid polymer injection. We investigate the particular case when a porous preform is located within the mould, so that the liquid polymer flows through a porous medium during the filling stage. The nonlinearity of the governing system of PDEs is due to the non-Newtonian behavior of the polymer, as well as due to the moving free boundary. The latter is related to the penetration front and a Stefan type problem is formulated to account for it. A finite-volume method is used to approximate the given differential problem. Results of numerical experiments are presented.
We also solve an inverse problem and present algorithms for the determination of the absolute preform permeability coefficient in the case when the velocity of the penetration front is known from measurements. In both cases (direct and inverse problems) we emphasize on the specifics related to the non-Newtonian behavior of the polymer. For completeness, we discuss also the Newtonian case. Results of some experimental measurements are presented and discussed.
Keywords: Liquid Polymer Moulding, Modelling, Simulation, Infiltration, Front Propagation, non-Newtonian flow in porous media
(43 pages, 2004)

64. T. Hanne, H. Neu

Simulating Human Resources in Software Development Processes

In this paper, we discuss approaches related to the explicit modeling of human beings in software development processes. While in most older simulation models of software development processes, esp. those of the system dynamics type, humans are only represented as a labor pool, more recent models of the discrete-event simulation type require representations of individual humans. In that case, particularities regarding the person become more relevant. These individual effects are either considered as stochastic variations of productivity, or an explanation is sought based on individual characteristics, such as skills for instance. In this paper, we explore such possibilities by recurring to some basic results in psychology, sociology, and labor science. Various specific models for representing human effects in software process simulation are discussed.
Keywords: Human resource modeling, software process, productivity, human factors, learning curve
(14 pages, 2004)

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