GRUBE-V: A SPECIALISTS` SOFTWARE IN A GROUPWARE ENVIRONMENT

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ABSTRACT

The success of planning an underground mine depends both on individual and group performance. The one is not much worth without the other.

During the early 1990s, a specialized ventilation simulation package called GRUBE-V[1] was installed at various mines of the German hard coal industry. Its main features were the computation of compressible air flows and a graphical user interface based on a 3D-model of the mine. The first part of the paper will focus on the fluid-mechanical background as well as the main characteristics of the user interface. The second part of the paper focusses on groupware features tailored to the need of mine planning as a group activity.

KEYWORDS

Subsurface mine ventilation, simulation package, groupware functions, German hard coal industry, GRUBE

INTRODUCTION

The design of a mine`s ventilation system is highly dependent on the results of the planning results of various other departments. Here are some examples:

- a change of longwall output may necessitate a different airflow to sufficiently dilute mine gas
- the expected cross section of a road dramatically affects air flow resistance, so various prognostications of subsidence are of great relevance
- the choice of the belt of a conveyor may have serious implications in case of fire and poisonous pollutants

Besides, many planning activities are closely interconnected via the time schedule and logistics. A slight change of a working`s starting date or its duration may trigger off wearisome administrative workflows to get material and human ressources properly re-planned.

Anyone familiar with workaday life on a large mine could easily carry on this list with many more detailed examples.

The problem is: who knows what is which of relevance to whom? Practically, all solutions to this problem must range somehwere between a constant bombardment of trivial bits of data and a complete refusal to let other people look into one`s own work in progress.

Obviously, some filtering must take place. Experience has shown that it easier for a recipient of some information to assess its relevance than it would be for the sender.

Suppose, for example, a ventilation engineer overhears a conversation between two miners in the cafeteria. He picks up that some dinting machines in a certain working have broken down and there is no substitute for the time being. From this information, he may infer that the airflow through that section may soon be reduced due to subsidence. If airflow at this specific point is crucial to the whole ventilation system, he probably wants to evaluate the exact risks involved. The miners, however, would most likely never have thought of informing the ventilation department.

Much important information between different departments takes this rather probabilistic way via informal communication channels. So we can expect much more information to be never exchanged in time at all.

The aim of the PC-application presented in this paper is to make specialists` planning results presentable to non-specialists within a PC-environment. The effect should be that engineers

[1] GRUBE-V (computer aided mine design, ventilation) is distributed by XGraphic Ingenieurgesellschaft Aachen, Kackertstraße 16-18, 52072 Aachen, Germany, e-mail: kontakt@xgraphic.de, Internet: www.xgraphic.de

and staff take an interest in their colleagues` work and habitually or casually "scan over" it from time to time to filter them for relevant data.

GRUBE-V is just one of large number of mining software applications grouped together under the name "GRUBE" (Grafischer Rechnerunterstützter Bergwerksentwurf = computer aided mine design).

All GRUBE applications communicate via a mine-wide data-base. Data of trans-departmental interest can be accessed both via a browser-like, text based interface as well as a 3D presentation of the mine. Files created by all these systems must obey certain conventions as to their names and technical accessability.

The first part of this paper briefly describes the theoretical background of GRUBE-V whereas the second part concentrates on features supporting mine-design as a group activity.

THEORETICAL ASPECTS OF VENTILATION NETWORK ANALYSIS

Until the mid-1980ies, the physical models used for the computation of mine-ventilation systems neglected the compressibility of air. In that sense, they were models of incompressible fluids rather than air.

With the average depth of mines nearing 1000m, however, it became clear that errors due to the inaccuracy of the model became more and more difficult to deal with. McPershon (1993, page 134) suggests that the compressibility of air should be considered for mines deeper than 500 m.

Extensive arguments in favour of a "compressible calculation" are given by Pollak (1985/1). It is shown, for instance, that results in drop of pressure and air flow power differ up to 56% depending on whether air flow was assumed to be compressible or incompressible in a realistic example.

Consequently, an algorithmic solution for the calculation of compressible airflow was implemented as a software application called "Wetter"[2] for the German hard coal industry. A detailed description is given by Pollak (1985/2). It is this algorithmic kernel which is being used internally by GRUBE-V to simulate ventilation networks.

The description below is therefore mainly taken from the initial publications by Pollak (1985/1; 1985/2) and should enable the expert to evaluate the inherent merits and limitations of the network simulation. The model is specified by the following equations, which describe different parameters of an airway between two arbitrary points denoted by the indices "1" and "2":

$$p_1 - p_2 = \Delta p_r + \Delta p_s \tag{1}$$

$$\Delta p_r = R_n \frac{\dot{m}^2}{\rho_m \rho_n} = R_n \dot{V}^2{}_m \frac{\rho_m}{\rho_n} \tag{2}$$

$$\Delta p_s = \rho_m g(z_2 - z_1) \tag{3}$$

$$P_r = R_n \frac{m^3}{\rho_1 \rho_2 \rho_n} = RnV^3 m \frac{\rho^3{}_m}{\rho_1 \rho_2 \rho} \tag{4}$$

with

$$R_n = \left(\lambda \frac{UL}{4A} + \zeta\right) \frac{\rho_n}{2A^2} \tag{5}$$

$$\rho_m = (\rho_1 + \rho_2)/2 \tag{6}$$

$$\rho_n = \rho(0°C, 1013 mbar) = 1{,}292 kg/m^3 \tag{7}$$

$$\dot{V}_m = \dot{m}/\rho_m = \dot{V}_1 \frac{\rho_1}{\rho_m} = \dot{V}_2 \frac{\rho_2}{\rho_m} \tag{8}$$

$$\rho = p/(RT) \tag{9}$$

where

A = cross-section of road
Δp = pressure drop
λ = coefficient of friction
g = gravitational acceleration of earth = 9.81 m/s²
p = air pressure
p_s = static pressure
R_n = norm resistance for turbulent airflow
P_r = loss of power of airflow due to friction
ρ_m = average density of air in the road
ρ_n = norm densitiy of dry air = 1,292 kg/m³
ρ = density of air
R = gas constant for particular gas or mixture of gases
ζ = resistance coefficient of local decreases of pressure
T = thermodynamic temperature
U = perimeter of airway
$\dot{V}_m$ = average airflow
z = elevation

According to equation 1, the difference in barometric pressure between two points equals the drop of pressure Δp_r due to friction plus the static

[2] by "Deutsche Montantechnologie GmbH, Am Technologiepark 1, 45307 Essen, Germany

pressure of the corresponding air column between the two points Δp_s.

Equation 2 gives the law of resistance applied to a ventilation network with $\dot{m}$ as mass flow, $\dot{V}$ as the average airflow and ρ_m as the average density of the air. "Average" relates to the airway in question. ρ_n is an arbitrary constant factor representing air at 0° and 1023 mbar. It simply serves to make sure that the artificially introduced norm-resistance R_n and the conventionally used resistance R have similar physical units.

According to Pollak (1985/2) it became necessary to define a resistance which is independent of air density. The reason for this is to properly deal with the changes of state of the air without unduly complicating the mathematical solution.

Equation 3 gives the difference of the static pressure between two points of different elevation z_1 and z_2.

The loss of power due to friction P_r is given by equation 4.

Equation 5 shows that R_n can be defined solely in terms of airway geometry, the coefficient of friction λ and a term representing local decreases of pressure ζ..

The average air density of a road ρ_m is given by equation 6. Theoretically the logarithmic average should be used in equation 2, but according to Pollak (1985/2) the error is tolerable.

Equation 7 simply defines the norm-density of air as used by the algorithm.

Equation 8 states the relationship between the average airflow between two points, average density and the constant mass flow.

Finally, equation 9 states the general gas law as a relationship between the density ρ of air, pressure p and the gas constant R for a particular gas or a mixture of gasses.

One limitation of the model is that temperature is modelled as a linear function of the distance the airflow has moved along an airway. In reality, temperature need not necessarily be a linear function of the way between two nodes of a branch. According to Pollak (1985/2) this is necessary to avoid clumsy mathematical solutions that are not suitable for practical use on mines.

The equations described so far only considered the airflow between two points with a single connection between them. Grouping them together into a network, one gets meshes and nodes.

The theory of networks is extensively laid out in the literature. See McPershon (1993) for instance. It should suffice here to say, that Kirchhoff`s two laws are used by the algorithm:

Kirchhoff`s first law states that the net mass flow entering any one node equals the mass flow leaving the same node.

Kirchhoff`s second law states that the algebraic sum of all pressure drops along a closed path equals zero.

Although networks resulting from the interconnection of branches and nodes can in theory be solved analytically, only numerical methods are used for larger networks today to minimize computational expenses.

The method most commonly used is called the Hardy Cross technique. It is extensively described in literature. See McPershon (1993, page 221) or Cerbe (1999, page 144) for example.

Based on the theoretical foundations described above, the algorithmic scope of GRUBE-V can be characterised by the following features:

- airflow is modelled as compressible
- natural buoyancy can be simulated
- consequently, ventilator failure can be simulated
- the influence of hot gases (explosions, fires) can be simulated by means of user-defined termperatures along an airway in addition to temperatures defined at nodes
- resistance can either be stated by the user explicitly or in terms of geometric roadway properties
- fan properties are described as pressure-volume flow characteristic curves
- distribution of air-pollutants can be simulated (diesel fumes, CH_4, incendiary fumes etc.)

USER INTERACTION VIA 3D-MODEL

The standard mode of user interaction is via a three-dimensional view of the mine provided by AutoCAD.

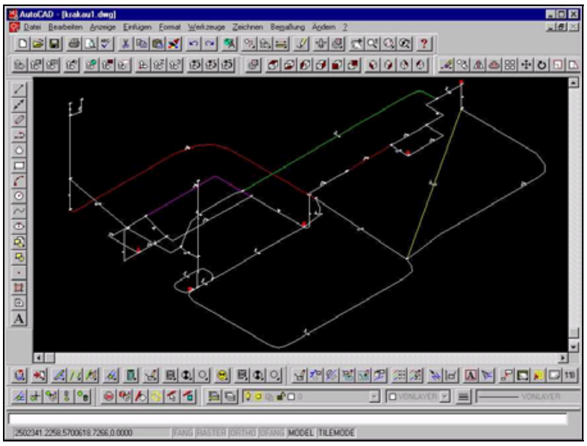

Figure 1: general layout of GRUBE-V

In addition to the specific functions for ventilation network analysis the user can utilize the full range of AutoCAD tools to manipulate the model.

The most common way to input data is via form boxes which can be opened by clicking on a branch or node of the model.

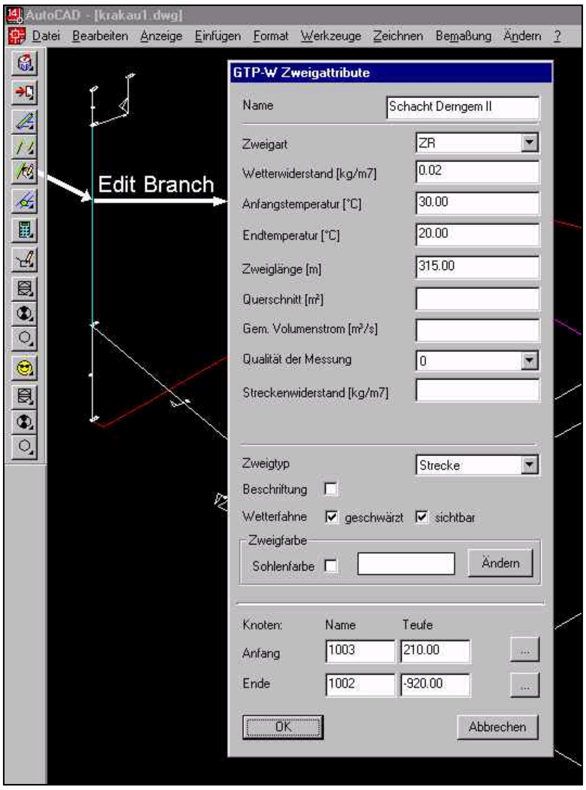

Figure 2: editing data via 3D model

The results of a calculation are presented in a similar manner. Alternatively, all input data can be edited and viewed in tabular style.

GENERATING DIFFERENT VERSIONS

Working on one and the same 3D-network, the user may wish to carry out different calculations. He may, for instance, want to simulate a fire, ventilator failure or different assumptions of temperatures, roadway subsidence or gas emission and store these versions as separate files.

To do so, any number of technical layouts can be attributed to any one 3D network.

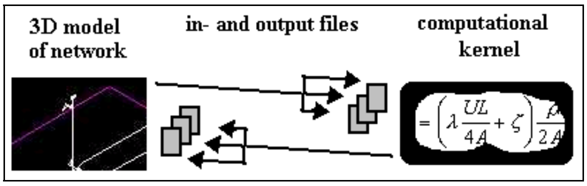

Figure 3: generating versions

The 3D model is stored as an independent dwg-file, whereas the in- and output files communicating with the computational kernel are stored as dat.files.

This, however, bears the danger of confusion as it is up to the user to organize his file-system in an unambigous way. It will be shown later, how this problem can also be dealt with.

So far, everything that has been described can be saved on a local PC without anybody other than the original author having access to the data.

PUBLISHING A VENTILATION SIMULATION

GRUBE is a generic term used for a range of different technical applications that all share a minimum set of standards to make them compatible with one another. In recent years, an information management system has been developed and installed at various mines. That system, described by Heim (2000/1 and 2000/2), serves to make planning data from a number of different sources available to experts and non-experts alike through the exclusive use of a single interface.The idea is, to provide some sort of "technical browser".

In that sense, "publishing" the results of one`s own work means making the data available to GRUBE information management.

Technically, this is done by transferring all relevant data from the local hard drive to a mine-wide database or to a corresponding file-system.

At this stage, the user has to specify the name of the ventilation network in a way that can be interpreted by outsiders:

- the working to which the simulation relates must be stated
- it must be stated whether the simulation is a prediction, a presentation of a life situation or whether it relates to past project (i. e. archived)
- the users identification number and the date are automatically inserted

The important point is, that it is up to the user to decide whether and when he wants to make his work available to a wider public.

The distinction between private and public data is indeed a powerful filtering tool to guard colleagues from useless information and also to safeguard oneself against unwanted interference.

There are a number of other optional denotations, but their meaning is customized to the needs of the German hard coal industry and therefore need not be stated.

VENTILATION SIMULATION IN THE CONTEXT OF A LARGER PROJECT

Once published in the GRUBE environment, a network has the status of a "virtual planning object" or also called an "information carrier".

The GRUBE information system groups together results from various applications, as shown in figure 4.

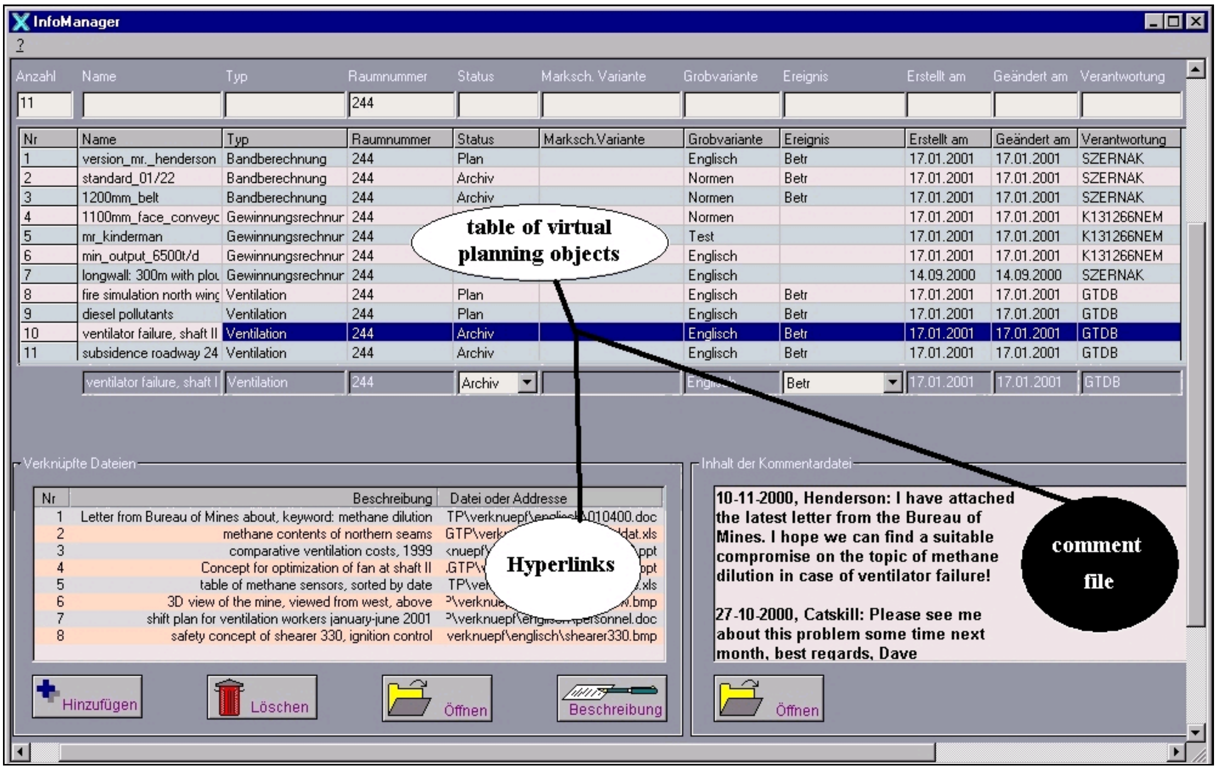

Figure 4: GRUBE information management

The "table of virtual planning objects" lists all published files that were created by any GRUBE-compatible application. In that sense, it can be likened to a file-manager. Each line represents a file, specified by its name, type, working point number (Raumnummer), status (planning,operational, archived) and various others. These denominators of files can be used for filtering operations. Thus, it only takes a few mouse-clicks to produce a list containing all published data that

- belongs to a certain working point number (244 in figure 4)
- has been created by a certain person
- has been published before a certain data
- contains a certai string like "shaft" etc.

Experience has shown, that within a few weeks, the number of files created exceeds a few thousand.

In the situation shown in figure 4, a file created by GRUBE-V, is marked blue, indicating that is activ. At the bottom left, a window shows all hyperlinks connected with that file. In the example above, these are mainly MS-office files giving some background information like a letter from the Bureau of Mines, tables, shift plans etc. A file can be opened by simply double-clicking on it. Also, the various computational versions connected to one network model are automatically set up as links and appear in that window, where the author can give them a telling name.

At the bottom right, anyone can quickly jot down a comment on anyone file.

It is also possible to activate a quick view of the layout of a ventilation network, a longwall design or belt-conveyor layout without having to start the corresponding application.

All these features help to encourage different people to take an interest in their colleagues` work. This anwers to the questions originally laid out in the introduction of this paper, namely the problem of trans-departmental information processes.

CURRENT PROBLEMS AND FUTURE PROSPECTS

Given that ressources for software development and maintenance are limited it is obvious that anything that goes into groupware support must be taken from specialized features.

Specialists, however, must lay a strong stress on their immediate interests. So the only practical way to deal with this dilemma is to identify groupware features that are also of immediate use to the expert. It is hoped that the system presented here fulfils this requirement.

We have also experienced that large software systems need a high degree of data-consistency and longevity. In some cases, this may run contrary to the need of flexibility and "easy solutions". Much thought has to go into carefully finding the right compromise.

But we are quite convinced that future software applications will only survive if they allow themselves to be integrated into groupware environments. As shown by Bodker (1999), questions like workflow management, supporting mobile meetings, activity awareness, virtual realities, collaborative authoring etc. are common to all sorts of industries. Accordingly, the answer in form of highly standardized software solutions like SAP or Lotus Notes will establish a standard others have to adapt to.

GRUBE, therefore, does not claim to be a groupware in the full meaning of the word. It rather aims at structuring data in a way as to make it adaptable to future developments.

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