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AUTOMATION OF THE RIJNLAND STORAGE BASIN, THE NETHERLANDS

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ABSTRACT: The project "Automation of the storage Basin Rijnland" (ABR), was finalised at the beginning of the year 2000, that is three years later than originally planned. The project has resulted in an automatic control system for four drainage pumping stations (total capacity 150 m^3/s) and an intake structure. The system can be operated with or without the intervention of a water manager. The original design of the system however, appeared not to function in practice. The system is currently running according to expectation, but its design has been adjusted drastically.

INTRODUCTION

In recent years, much has been written about fully automated systems also denoted as real time control (RTC) systems or Decision Support Systems (DSS). Despite this attention, in practice few of these systems are operational in such a way that they can actually replace operational management. Despite the advancement in the automation of pumping stations and other actuators, automated *operational management* is rarely seen. Automated operational management is defined here as daily management that can be carried without human intervention. In the past, various attempts have been made to realise automated operational management. (Geldof et. al. 1993).

In 1992 the waterboard of Rijnland commenced enthusiastically with the ABR-project (Automatision Rijnland storage Basin) with the aim to design an automated operational management system. The ambition was to design a system that could be used to regulate remotely without human intervention. The system had to carry out the day to day storage basin maintenance, without intervention by the water manager. Furthermore, the system also had to warn and advise the water manager under both normal and atypical conditions (Breur et.al. 1999).

In 1997, the ABR-project was delayed, cost more than budgeted and furthermore, the system did not function as well as expected following completion. It seemed that in this project the original ambitions would not be fulfilled. But through sheer persistence by the customer as well as by the developers, the ambitions were eventually reached. In this article, the development process from 1997 onwards is considered in a frank manner, in the assumption that others can learn more from accounts of mistakes than stories of success.

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THE RIJNLAND WATER MANAGEMENT SYSTEM

The water system of Rijnland is situated in the urbanized western part of the Netherlands. The catchment area consist of 170 polders (total area 700 km^2) and higher grounds (total area 300 km^2). During the winter period, the polders and higher grounds discharge their excess of water to a network of so called "bossom canals". In the summer period the bossom canals function as water supply canals.

Fig. 1 The canal network of Rijnland, called bossom canals, is controlled by four drainage pumping stations (capacity 150 m^3/s) . The aim of the project was to build a Real Time Control system for the operation of the pumping stations.

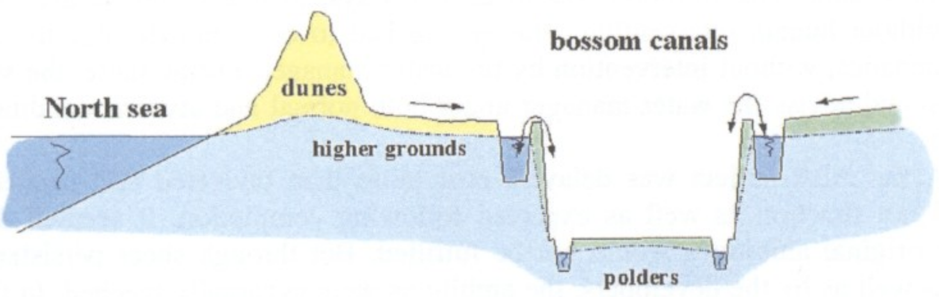

Fig. 2 Side view of the Rijnland water management system. The bossom canals receive drainage water form higher grounds and low-lying polders.

The water level in the bossom canals is controlled within centimeters by four pumping stations with a total capacity of 150 m^3/s. The ongoing urbanisation in the polder areas causes an increase of the peak discharge. Instead of increasing the pump capacity of the bossom canal with 20%, the waterboard decided to improve the control of the existing pumping stations.

RATIONALE FOR THE PROJECT

The rationale for the ABR-project originates from 1992. In that year, it was first realised that with the implementation of a reliable and vigilant storage basin management, a significant increase in the pumping capacity could be delayed. Alongside the automation of the pumping stations, the ABR-project foresaw the development of an automated management system that could take over the daily tasks of the water manager and could advice and warn the water manager if conditions required so. By investing in the automation (including the required adaptations to the existing pumping stations) money could be saved on the investment for additional pump capacity (approximately 10 million euros).

Consequently, a development course was set out. In the first phase the program of demands was established. In the following phases the basic design, the final design and the implementation were carried out. According to plan, the ABR-project would have been finalised in 1997 (Kruiningen et. al. 1997), (Werner et. al. 1997).

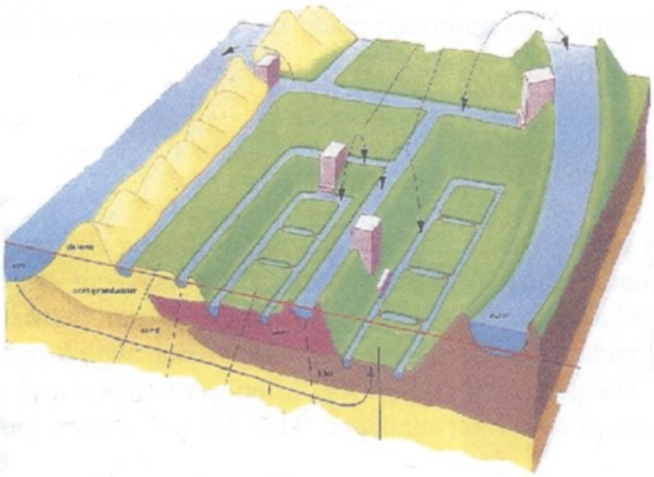

Fig. 3 Schematic representation of the Rijnland storage basin consisting of canals. An area of about 1000 km^2, mainly consisting of polders, drains its water to the storage basin during the winter period and derives its water from the basin in the summer period.

Fig. 4 Impression of an older part of the bossom canal in Rijnland. The allowable water level fluctuation in the basin is only 0.05 m.

CHARACTERISTICS OF THE ORIGINAL APPROACH

If one looks back at the original approach to the development of the ABR-system, a few matters can be noted.

Instead of using standard software, much of the software was tailor-made. The automated measuring system, for instance, was developed under own management, so as not to be dependent on external suppliers. The ABR-system was also developed from scratch. Although certain parts consisted of current software, such as the simulation models, these were consequently adapted to the specific demands and wishes.

The use of mathematical models to make the ABR-system "sufficiently intelligent" was relied on heavily (Vermeulen et al. 1994). At the time these models were considered vital to allow the system to take over the tasks of the water manager or to allow the system to adequately advise the manager. The models that were used consisted of two rainfall runoff models a hydrodynamic flow model and a water quality model (Sobek 2000). To ensure that the models agreed continuously with reality, data-assimilation techniques were used, such as Extended Kalman Filtering. This approach made the development of the ABR-system highly complex.

PROBLEMS ENCOUNTERED

Despite a thorough preliminary study and a structured development approach, the system did not function adequately during the test phase. The measuring system and the automated data acquisition system functioned well, but the decision part of the ABR-system showed signs of flaws, which included: The system was not robust, which meant it failed often and thus was not reliable. The proposed advice was often not realistic and did not agree with the thoughts and gut feeling of the water manager. This did not inspire the water managers with much confidence.

After years of concerns, the problems seemed so great and the confidence in a successful conclusion to the project seemed so minute, that the whole project came close to being brought to an end in 1998. This would not only have had severe repercussions for the waterboard of Rijnland, but it would also have affected the reputation of the developers and the general feelings of expectation people had in the automation of operational water management.

RESTRUCTURING PLAN

When it became obvious that the problems encountered could not be solved with small adjustments, a general state of mind arose, whereby the various parties involved in the development, hid behind each of their own contributions to the system. To break through this process a mutual initiative by the waterboard of Rijnland and WL Delft Hydraulics was undertaken at the end of 1998 to restart the project. The new project would be carried out by a new project team.

Initially the new project team produced a restructuring plan, in which an overview was given of all the problems. After analysing the problems it became clear that radical decisions and adjustments were required to successfully complete the ABR-project. All adjustments that had already been carried out, had not brought the solution any closer. It was therefore decided to critically review a large number of the original decisions. In practice, this meant that in a short time the whole development course, from the definition study, basic design, detailed design and implementation, was redone.

OVERVIEW OF THE PROBLEMS CONCERNING THE CONTENT

It became clear that, despite all good intentions throughout the developmental stages, the system was not a modular one. The whole system was therefore vulnerable to malfunctions, difficult to maintain and showed a slow performance. For instance, it took more than three hours to provide an updated advice concerning the application of the pumping stations.

The software architecture appeared to be very complex, partly due to the inclusion of the various intermediary solutions. Data were checked in various different places and data conversions were also carried out in many different places. Furthermore, original standard software was modified. Therefore updates, that were subsequently released, could not be used anymore.

The use of simulation models and the application of data-assimilation techniques appeared to be unclear. In fact their necessity had never been demonstrated. Because the mathematical models formed the spine of the decision system, the advice was highly dependent on the adequate functioning of all models. Data-assimilation (such as Kalman filtering) should have guaranteed the accuracy, but inherent uncertainties, such as rainfall predictions, were not adequately taken into account.

In short, for the determination of a updated advice, many links were required. If one link broke, the system crashed. Naturally, data checks and procedures had been implemented to avoid such situations, but as a whole the system had become so complex that new flaws were constantly being discovered.

CONTINUATION

To convince all parties of, on the one hand, the necessity to remove parts and, on the other hand, to make adjustments to the system, many intensive sessions were held. On a weekly basis, lengthy and sometimes heated discussions were held with all parties involved. This process took over four months. The result was a widely supported and well thought out re-design plan.

During this period the ABR-system was stripped of all mathematical models and key tasks. In this way it became possible to test the system's ability of acquiring and efficiently guiding the correct data throughout the system. At this stage, no attention was paid to the quality of the system's advice.

RECONSTRUCTION

On the basis of the re-designed plan and the stripped ABR system, the system was reconstructed step by step in the spring of 1999.

In the first step, the complex internal data structure was radically simplified. Thus various data conversion processes could be avoided. Unnecessary and incomplete validation checks were removed and concentrated in one place. This way a better overview of the whole system was obtained and, moreover, the processing time was reduced considerably and brought back from hours to minutes.

Subsequently, a rainfall runoff model (Sobek) was added to the decision cycle. This model made it possible to accurately estimate the inflow using current precipitation and (measured and predicted) evaporation data. By using the predicted rainfall data, the system is able to anticipate on storm events. It became evident that data assimilation procedures were not required.

Then, the core of the decision system was modified. The (artificial) intelligence that is required for this is no longer derived from complex physical mathematical models, but based on control rules (Schuurmans J. et.al. 1997), (Schuurmans W. et. al. 1999). These controllers appeared to be perfectly capable of dealing with the inherent uncertainties, such as those involved with the predicted water inflows. The advice is based on actual water levels and predicted inflows. The advice is updated every hour instead of every four hours in the original system. In this way the water manager always has an up to date advice and the system responds adequately to unexpected (precipitation) situations.

Finally the user interface has been modified. A large number of screens appeared to be non-functional and have been removed. Instead a new overview screen was designed, showing almost all the information relevant to the water manager. It enables the water manager to view the advice and to make his (or her) own alterations. The impact of these alterations, on the average storage basin water level, is shown directly.

The new instruction (the original advice or manually altered advice) is automatically sent to the pumping stations every hour. The complete system can also be operated at home using a laptop PC.

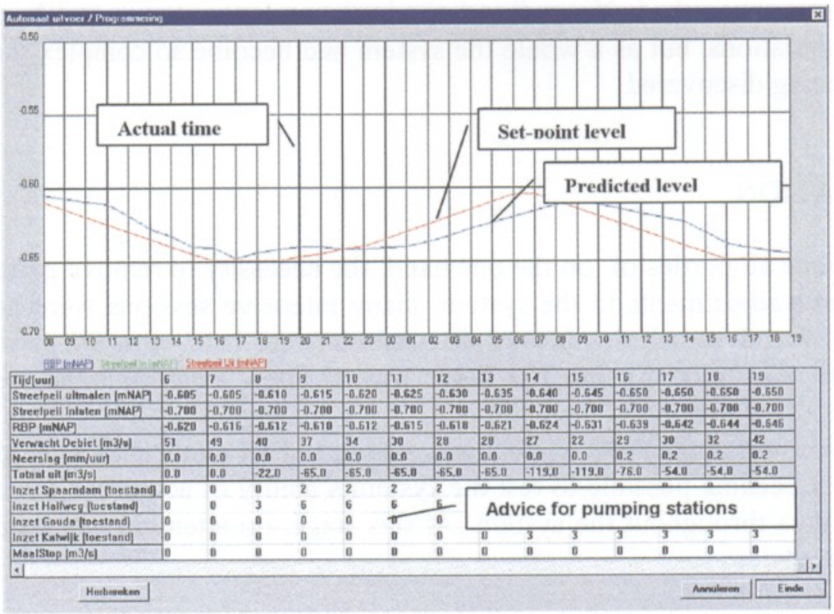

Fig. 5 Screen dump of the user interface of the control system, showing the measured and predicted water level. The advised pumping schedule is shown in the table below the graph. The operator is able to change the set-point for the water level. The screen is automatically updated with real time data.

THE SIMULATION MODELS AND THE LONG TERM DATABASE

The hydrodynamic simulation model and water quality model have been removed from the on-line decision system. In the new system they are moved to an off-line "desk setup". Here the water manager can carry out simulations on his/her own accord, for example to evaluate the effects of possible extreme situations or intended measures. When a simulation is run, all required current information can be easily copied to the desk setup from the ABR-system. In the desk setup only the standard models are used, which can be updated with new versions.

Each day more than 10.000 data are acquired and checked by the system. The long term database for the archiving and post-processing of all this information was originally a new purpose-designed product. This database has been replaced by standard software (HYMOS). Periodically (weekly or monthly) the water manager can export all the information from the ABR-system to the long term database. The standard functionalities of the database conform highly to the demands and wishes of the waterboard of Rijnland, including for example, a coupling with the off-line Sobek simulation models, statistical analyses, data processing and the generation of reports.

LESSONS AND TIPS

Although each automation project is, almost by definition, unique for the water system it is used for, a few lessons can be learnt from the Rijnland ABR-project:

1) Any automation project, like the one described here, is an IT (Information Technology) project and should be considered as such. This means that the data structure and data processing procedures determine the reliability, robustness and performance of the system. From a water management point of view, the core of the system is the decision module. From an IT point of view, the decision module is just one the software modules ofthe entire automated system.

2) It is recommended to make use of standard software, and to keep the software standard. In other words, do not make any specific changes to the standard software. After carrying out modifications, however small they may appear, standard software is no longer standard, and updates of the standard software can not be used.

3) Murphy's law "everything that can go wrong, will go wrong", is applicable to everything that has not been clearly detailed and understood from the beginning. In that respect, seemingly small details can determine the robustness and ability to maintain the system. During the design phase, every aspect must be well thought out and documented.

4) The use of mathematical models (with or without the combination with data-assimilation) is not necessary for an intelligent advice and control system. Control rules well known in measurement and control engineering, are reliable and perfectly adequate to run complex water systems. These techniques have been proven to work with practically all (industrial) processes and from an ICT point of view they are much simpler in design than complex models.

5) Adding too many unnecessary "bells and whistles" to a system can make it vulnerable, difficult to maintain and costly. Extra elements should be added step by step and only after the added benefit has been emphatically determined.

6) The difference between carrying out a desk study for an automated operational water management system and actually delivering an infallible automated system is immense. Many techniques and models that are essential and practical for a system that is used during a desk study, are often not usable in practice where it has to function under all conceivable practical circumstances.

7) In the design stage "you should not walk before you can crawl". It is preferential to design and deliver a system with basic functions in a short space of time and then expand it with extra functions instead of design and deliver a complex system as a first product. A short design phase and early implementation allows for an early assessment of the concepts in

practice. This way the discovery that certain concepts do not work in practice after a long (and expensive) design phase, is prevented.

MORAL OF THE STORY

Together with the continuing advancements in the automation of the remote operation of pumping stations and gates in complex water systems, the use of automated operational system (also denoted as RTC (Real Time Control) or DSS (Decision Support Systems) shall become more widely accepted in the future. The question "why should we use an automated operational management system?" will be replaced by "why *shouldn't* we use such a system?". After all, complex water systems continuously require a meticulous management.

The ABR-project that after all has been successfully completed shows that is possible to design a highly functional system for large scale and complex water systems. The ABR-system warns, advises and can take over the daily management tasks of the water manager. Such a system does not have to be "complicated" to become "intelligent". It has been demonstrated that the original use of on-line simulation models in combination with data assimilation techniques was not necessary and even undesirable from the point of view of simplicity and robustness. Developing a simple system does however require knowledge, skills, experience and a certain degree of daring. Hopefully the experiences in Rijnland, will provide a stimulus for others to undertake the development of operational management control systems.

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