Designing Virtual River: A Serious Gaming Environment to Collaboratively Explore Management Strategies in River and Floodplain Maintenance

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Abstract. Dutch river management is in transition from a phase of intervention and implementation to a phase of maintenance. In light of this transition, we discuss initial results towards the development of a serious gaming environment where river and floodplain management actors can collaboratively explore intervention and maintenance strategies. We introduce the design approach of a serious gaming environment based on qualitative interviews with river and floodplain maintenance actors. Based on these interviews, we identified two key variables to explore strategies for river and floodplain maintenance: maintenance intervals and floodplain scaling. We proceed with presenting the Virtual River; a concept for a serious gaming environment. In this environment, actors can play out intervention and maintenance scenarios around these two key variables over time using simplified hydrological, morphodynamic and vegetation models.

1 Introduction

Serious games are finding their way more and more in river management as tools for training, for raising awareness as well as for creating shared understanding [1–8]. This is not surprising as river management is an inherently complex socio-technical system and serious games are well suited to address such systems [9, 10]. A particular complex socio-technical river system is the Dutch Rhine-Meuse Delta. This delta area is prone to flooding[1], inhabits a large percentage of the Dutch population and is vital to the Dutch economy[2]. Currently, river management in the Rhine-Meuse Delta is entering a phase of maintenance following the (near) completion of many large-scale riverine projects [11]. As these projects transitioned river management to forms of adaptive (co-)management

[1] Over 60% of the Netherlands is prone to flooding from either the sea or rivers.
[2] For example, the Waal river, a Rhine branch, is the main shipping route from the Rotterdam harbor to the industrial Ruhr region in Germany.

R. Bottino et al. (Eds.): GALA 2016, LNCS 10056, pp. 24–34, 2016.
DOI: 10.1007/978-3-319-50182-6_3

[12], this maintenance phase bears the challenge of sustaining this adaptive approach to river management.

In response to these developments, our research focuses on developing a serious gaming environment where actors can collaboratively explore management strategies in river and floodplain interventions and maintenance. In this paper, we present preliminary results of our research and a concept for the serious gaming environment based on identifying key variables in river and floodplain maintenance. In Sect. 2, we briefly introduce the context of river management in the Netherlands and discuss the implications of the upcoming maintenance phase. In Sect. 3, we review serious games applications in river management according to two identified categories. Next, we use this review as well as the river management context to frame the approach for our serious gaming environment. In Sect. 4, we present and discuss the interview method we are using to explore possible directions for the serious gaming environment. In Sect. 5, we present key variables identified in on-going interviews with river management actors. In Sect. 6, we describe the concept of our serious gaming environment, Virtual River, based on these identified variables. Finally, we conclude with remarks for the next steps in the development of Virtual River.

2 Dutch River Management: Room for the River

That the Rhine and Meuse rivers both nearly flooded in both 1993 and 1995 took the Netherlands by surprise and renewed the focus on river management. River management can be described as the continuous activities of human intervention in river systems in order to produce or retain some defined objective(s) in regard to river functions such as water safety, navigation, nature development or agriculture. The 1993 and 1995 events sparked the ‘Room for the River’ (RvdR) program; a combination of riverine projects in the Dutch Rhine-Meuse delta aimed at increasing flood safety by creating space for water [13]. With the emphasis on space for water, secondary objectives towards for example nature, housing, recreation and business were included in the projects under the guise of ‘enhancing spatial quality’. The RvdR program transformed flood prevention in river management from ‘resistance’ to ‘resilience’ [13]. This river management transformation can be considered a transition to adaptive (co-)management [12]; a form of management that explicitly links learning – both experiential and experimental – and collaboration in order to facilitate effective governance [14, 15].

Given that all RvdR projects are (nearly) completed, Dutch river management is now transitioning to a post-RvdR maintenance phase. New dilemmas are emerging within this transition, especially in the floodplains of the rivers. As the name suggests, floodplains are an integral part of flood protection. However, since nature was a specific focus point within RvdR, many floodplains were converted into protected areas in cooperation with nature organizations to establish ‘self-regulating nature areas’ [16]. Many of these areas are now ‘Natura 2000’ areas; protected nature areas subjected to EU policy objectives.

In recent years, concerns have started to arise among water managers whether these self-regulating nature areas would severely affect the discharge capacity of the river system. Vegetation in the floodplains – especially thicket and forest areas – adds friction and obstruction to the water flow, lowering the amount of water that can safely be discharged. In response and in anticipation of RvdR's completion, the main Dutch water authority initiated the 'Streamline' program [16]. In this program – in execution at the time of writing – a large amount of vegetation in the Dutch floodplains is removed and 'reset' back to the norms of 1997, around the time when RvdR was initiated.

These combined developments have resulted in the so called 'nature-safety dilemma' where flood protection objectives are conflicting with nature objectives [16, 17]. Our research therefore focuses on developing a serious gaming environment where actors can collaboratively explore strategies in river and floodplain interventions, in particular those focusing on maintenance. In the next section, we review serious games applications in river management and frame the approach for our serious gaming environment.

3 Serious Gaming in River and Delta Management

A recognized strength of serious games is their ability to combine technical complexity with social complexity [9, 10]. It is therefore not surprising that serious games are increasingly used in river management as rivers are inherently complex socio-technical systems [18]. From this socio-technical perspective, two types of serious games in river management can be distinguished based on their relation to water. First are games where water is considered a (non-infinite) resource that can be used – e.g. for irrigation – and the use of water has an effect at the system level. Examples of such games are Aqua Republica [1], River Basin Game [2], PIEPLUE [3] and LASY [4]. In the second type, water is considered a boundary condition – e.g. low or high river discharges – leading to possible events – e.g. imminent droughts or floods. Examples of this type of games are the Sustainable Delta Game [5], STORM [6], FloodSim [7], and SimDelta [8].

The serious gaming environment we are developing falls under this second type and the mentioned serious games show similarities to our approach. For example, in the Sustainable Delta Game, players are presented with a non-existing, typical Dutch river basin and develop strategies to limit the probabilities of both floods and droughts occurring [5]. This way, players learn about the complex interplay between water management, climate change and changes in society. The STORM role-play game stimulates a dialogue between relevant stakeholders in a planning process of the Dutch Rhine and its floodplains [6]. As such, players are demonstrated with relevant stakeholder interests, the interaction between these interests, the types of conflict that might occur and the effects of human intervention to the physical system. In SimDelta, players are presented with interactive maps of scenarios. Each scenario describes problems and solutions which intend to explain the complexity of the Rhine-Meuse Delta [8]. The main objective of SimDelta is to provide this explanation faster and more intuitively than reports and presentations.

Although many differences can be noted, a major difference between these examples and our serious gaming environment approach is that we explicitly include monitoring and maintenance in river management over purely focusing on planning intervention measures. In particular, actors collaboratively explore integral strategies – from planning to maintenance – in the envisioned serious gaming environment as river management requires the coordination of resources not only for implementation, but also for monitoring and maintaining the functions of intervention measures [19].

Given this approach, our serious gaming environment can be characterized as serious gaming for self-organization based on Mayer et al.'s frame reflective discourse analysis [20]. In this category, actors expand their knowledge and understanding through interactions with others who may have different perceptions and ideas. Serious games in this frame therefore aim to affect the ways in which people organize and interact [20].

Serious gaming for self-organization can be linked directly to adaptive (co-)management; Olsson et al. include the *"self-organized process of learning-by-doing"* in their adaptive (co-)management definition [14]. A main driver in adaptive (co-)management is therefore social learning; *"a change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks"* [21]. Games, in particular role-playing games, have been recognized as a successful way to support social learning [9, 18] and many scholars have reported that gaming is indeed successful to establish social learning processes [22–24].

However, to facilitate social learning processes, a deeper understanding of context, power dynamics and values is needed that influence the ability of people and organizations to collaborate [25]. In the next section, we explain the method we used to gain this deeper understanding in search of concept directions.

4 Qualitative Interview Approach

We conducted interviews to gain a deeper understanding of the context of river and floodplain management as well as explore key variables that actors would like to able to experiment with in our serious gaming environment. We chose face-to-face qualitative interviews based on a semi-structured protocol as interviews are well suited to tap into motivations, perceptions, wishes and needs of participants [26].

We set up the interviews using a human-centered design approach to analyze use scenarios based on moving from remembering and experiencing to imagining and envisioning [27]. Within this approach, we used Dervin's sense-making methodology as a guide for our questions [28]. Dervin's sense-making methodology is based on the notion that a person, embedded in a context-laden *situation*, is faced with a *gap* (or a *sense-making need*) which prevents him/her from moving towards a *desired outcome*. To reach this outcome, the gap needs to *bridged*.

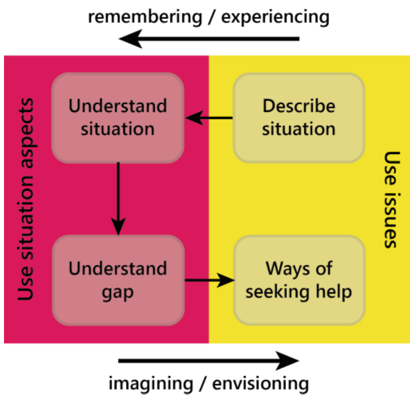

Fig. 1. Interview approach schematization based on Van der Bijl-Brouwer [27] and Dervin and Foreman-Wernet [28].

The interviews were set up semi structured and questions were divided into four phases following the schematization of Fig. 1: (1) introductory questions related to their work activities in order to describe the situation; (2) contextual questions related to a challenging situation in order to understand the situation; (3) specific questions regarding the participant's concerns, struggles and questions they had in the challenging situation in order to understand the gap; and (4) envisioning questions regarding preferred outcomes and help they would have liked in the challenging situation.

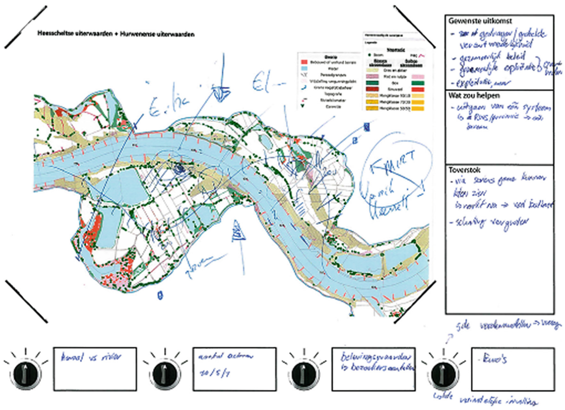

Fig. 2. Example of materials and results of the envisioning phase of the interview.

Throughout the second, third and fourth phase, we used maps – vegetation and satellite maps of river segments – to assist participants in reflecting on their challenging situation. Furthermore, we used a paper canvas around the maps for each phase. These paper canvasses served three functions: (1) as a guide for the interview and the structured questions; (2) as material for participants to provide direct feedback – writing or drawing –; and (3) as an initial verification of the notes we wrote down in relation to their responses. Figure 2 shows an example of the interview results including the map of the challenging situation, identified by the participant, and the fourth phase's paper canvas. The text boxes on the right related to questions on desired outcomes; what would help them achieve this and what would help them if they had a magic wand (no constraints). In the bottom of the fourth phase's canvas are four text boxes with dials next to them. These text boxes related to the identification of the key variables.

The participants we invited were contacted based on the criteria that they: (1) are representatives of organizations who are active in Dutch river and floodplain maintenance; (2) have more than five years of experience in river and floodplain maintenance; and (3) have a high position in their organization. The participants were part of organizations for water management (main Dutch water authority and regional water boards), governmental (ministries, provinces and municipalities), nature conservation (Dutch state forestry agency, regional landscape organizations and nature development organizations) and agriculture (agricultural nature organizations and farmers). As this is work in progress, 11 interviews were analyzed within the scope of this paper. We conducted all interviews at the offices of the participants. The interviews all lasted between 60 and 110 min and were recorded for transcription and coding. All participants were men.

5 Key Variables

Below, we present the initial results of our interviews in the form of two key variables for experimentation identified by multiple participants. We present and discuss the key variables and their background based on information obtained during the interviews. We used these key variables to develop our initial concept, which we discuss in the Sect. 6.

5.1 Key Variable 1: Maintenance Intervals

Both water managers and nature managers mentioned the exploration of the variable of maintenance intervals, albeit for very different reasons. In anticipation of the post-RvdR maintenance phase, the main Dutch water authority initiated the 'Streamline' program. This program effectively removes vegetation from the floodplains in order to increase water safety as vegetation lowers the river's discharge capacity. In parallel to this program, the Dutch water authority developed the so-called 'Vegetation layer': a categorized vegetation map of all floodplains of the Rhine and Meuse branches. Based on this map, maintenance concerning vegetation – e.g. removing fast growing vegetation – is executed at specified time intervals to keep all areas within the floodplain to their mapped category.

Nature managers stated that the Streamline program and the Vegetation layer are a thorn in the side as (1) they had just spent years developing nature in the floodplains as part of the RvdR program; and (2) they did not consider mapping and categorizing areas of the floodplains as nature development or conservation, but as – in their words – *"gardening"*. Combined, the nature managers felt the two developments would undo many promising nature development results and severely limit the possibilities to meet previously defined nature objectives. At the same time, the nature managers acknowledged that water safety is leading in floodplain maintenance.

The nature managers were convinced that extensive maintenance measures with longer intervals in between would be more cost-effective. In addition, this approach would allow *"surprises in nature to develop"* as floodplain conditions constantly vary. These surprises would be beneficial for the biodiversity of floodplains.

The water managers also mentioned the maintenance interval variable with cost-effectiveness in mind, albeit from a perspective of mapping and monitoring. The water managers explained that to develop the Vegetation layer, they used aerial photographs to map all floodplains. This mapping process was both costly and time-consuming (nine months). Therefore, this process is a problem in relation to (bi-) yearly maintenance as: (1) mapping each year is too costly; and (2) by the time mapping is completed, the resulting map is already outdated.

In light of this variable, both water and nature managers wondered what measures would be needed if interventions were only performed every five, ten or twenty years. They also asked what the extensiveness and costs of such measures would be and when it would be necessary to act in between maintenance intervals.

5.2 Key Variable 2: Floodplain Scaling

The variable of floodplain scaling was brought forward by both governmental actors and nature managers, but again for different reasons. Dutch floodplain maintenance is currently rather fragmented [16] as: (1) the mapping of vegetation in the floodplains is categorized on a local scale; and (2) the floodplains are owned by some 15,000 land owners [11]. Floodplain maintenance is therefore performed at a local level as opposed to on the level of a larger river segment. Even two opposing floodplains, divided only by the river itself, are monitored and maintained separately.

The nature managers stated that it is therefore very well possible that maintenance in floodplain A would be executed even though it is not needed as maintenance measures in opposing floodplain B were effective enough to reach the combined water safety objective for the river segment. A more integral approach of combining monitoring and maintenance of floodplain A and B could lead to more flexibility. From their perspective, this flexibility could be more cost-effective and would enable them to leave specific areas untouched when surprising nature developments occur.

Multiple governmental actors would also like to explore the floodplain scaling variable to establish cost-effective maintenance. Because of the fragmented ownership, there is very little coordination in maintenance activities. The local mapping and monitoring contributes to this lack of coordination. As a response, the governmental actors proposed forming coalitions between organizations involved in floodplain management in order to pool resources and coordinate maintenance efforts in a river segment. The floodplain scaling variable for the provincial government is therefore the length of the river segment in relation to the size – the amount of actors – of such coalitions.

Regarding the floodplain scaling variable, the governmental actors and nature managers stated that they would like to explore the benefits of looking at floodplains on a larger scale. Questions they put forward related to what the ecological flexibility would be at this larger scale, how they should approach monitoring and how floodplain maintenance at a larger scale can be organized.

6 Virtual River Concept

In our serious gaming environment concept, titled Virtual River, we combine the maintenance interval and floodplain scaling variables. In Virtual River, players – river management actors – can collaboratively explore management strategies while explicitly taking river and floodplain maintenance into account. To achieve this, we present players with a digital environment, a river stretch including floodplains, where they can play out management scenarios over time. We include simplified hydrological, morphodynamic and vegetation models to Virtual River in order to present players with realistic feedback on their actions in regard to the river's discharge capacity and vegetation development.

At the start, players join the game on their own console as a representative of a specific river management actor; either all players take on the role that they also have in reality or all players take on a role different from their traditional role. In the first level,

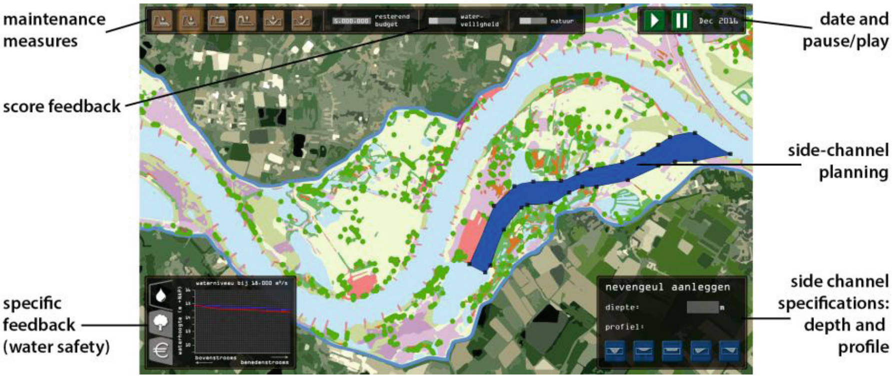

Fig. 3. Virtual River concept's main surface where a side-channel is drawn as a maintenance measure in the floodplain.

players are presented with a single floodplain area on a main surface where certain water safety and nature objectives have to be met (Fig. 3). Players are given the challenge to collectively develop strategies to meet these objectives. However, players also have individual objective(s) based on their roles. For example, a water manager could have the objective of limiting the maintenance costs to a given amount while a nature manager might have to objective to leave a certain area in the floodplain untouched. Based on their respective role, players also have their own resources. Water managers for example have a large budget available to them while nature managers have access to flocks of horses to graze the floodplains. Resources can also be very specific to their role; water managers for example have access to other monitoring options (e.g. aerial photographs) than nature managers (e.g. network of volunteers). Of course, such resources cannot be deployed limitlessly.

Collectively, players can look into possible intervention measures and their extensiveness based on the maintenance intervals. Measures are performed once per interval – e.g. digging a side-channel for the river (Fig. 3) – or continuous – e.g. horses grazing the floodplains to limit vegetation growth. Using the main surface, intervention measures and maintenance strategies are collectively discussed and planned. During this planning, the game provides players with some initial predictions on the effects towards water safety and nature objectives. Once the measure is put in place, players look into monitoring options and decide who is responsible for monitoring. At the same time, they also need to decide the conditions under which intervention is necessary in between maintenance intervals; there is an inherent level of uncertainty attached to riverine measures and perhaps a measure is not as effective as planned. Afterwards, time is started and players can use their consoles to monitor development, manage their own resources and request resources or actions from other players.

While exploring management scenarios, players can track their progress in relation to water safety and nature objectives as well as costs. As players put more extensive maintenance measures in place, thus increasing the maintenance interval, they experience that this has a positive effect on the nature objectives as less intervention provides more opportunities for nature. However, longer intervals have a negative effect on water safety as these add more uncertainty to the floodplain's development over time. In the end, players notice that reaching both the water safety and nature objectives is difficult and requires trade-offs. If players do not reach both objectives, they may choose either to explore other management strategies or to collectively adjust the flood safety and/or nature objectives and/or the budget in such a way that the objectives can be met.

In the second level, players are presented with a similar situation as the first level, with the main exception that now they are dealing with a river segment containing up to four separate floodplain areas. They are still provided with specific water safety and nature objectives, but can reach these objectives by combining measures in multiple floodplain areas. Similar to the first level, players experience that their decisions cause trade-offs between water safety and nature.

As players play out such maintenance scenarios over time, they experience (1) the trade-offs made between water safety and nature; (2) the uncertainty attached to the river system; and (3) the objectives of other river and floodplain management actors.

7 Concluding Remarks and Next Steps

In this paper, we set out to present a concept for a serious gaming environment in regard to river management based on identifying key game variables. Our interviews revealed two key variables that are interesting to pursue further as multiple participants mentioned these for different reasons. Moreover we presented Virtual River, a concept for our serious gaming environment, which plays into the unique opportunity to contribute to collaboration in a transition of river management phases in the Netherlands. Within Virtual River, players can play out river management scenarios over time and learn about trade-offs between water safety and nature, uncertainties attached to the river system and objectives of other actors.

However, Virtual River as presented here is still conceptual. After concluding the interviews, the next step in our research is therefore to iteratively develop Virtual River further together with actors in a particular case study as 'show case'. First, we will use paper prototyping in co-design sessions in order to (1) explore the key variables together with participants in-depth; and (2) explore how participants would like to work with these variables in the gaming environment. A focus point in these co-design sessions is to explore the options and feedback participants would like to have while playing in the game – e.g. the incorporated hydrological, morphodynamic and vegetation models – and at what level of detail. Following these co-design sessions, an early prototype will be developed and evaluated on usability.

Acknowledgements. Research for this paper was conducted as part of the program RiverCare: towards self-sustaining multifunctional rivers, funded by the Technology Foundation STW (Grant Number P12-P14). In addition, the authors would like to thank all interview participants for their participation and cooperation.

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