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Game Engineering for Hybrid Board Games

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Abstract -- Hybrid board games integrate aspects of a physical board game and a computer game. Such a setup creates new possibilities for game design, but also defines new challenges and open questions. This paper investigates on several aspects of hybrid board games including: (i) useful allocation of tasks and game elements between the analog and the digital part. (ii) hardware platforms for hybrid board games, and (iii) software frameworks supporting the development of the digital part of a hybrid board game. In a second part the paper reports about setting and results of a hybrid board game jam that was organized as a pre-conference event of the Future and Reality of Games Conference 2019.

Keywords: Hybrid game, Board game, Design, Prototyping, Platform, Game Engineering

Introduction

Hybrid games, defined as the combination of an analog and a digital game part are an exciting game category. The concept of hybrid games is not new, since tabletop games with electronic or digital elements have been realized since the 1970s (Kankainen and Tyni 2014), but up to now hybrid board games have received much less attention than pure video games or pure board games. A possible reason for this might be the increased complexity of games that had to be shipped with electronic components, electric wiring and required batteries to be played. With today's increased penetration of computers and, especially mobile devices, the tables have turned. A hybrid board game that is able to outsource part of its materials into a virtual digital part becomes now economically more feasible than a game without digital elements. Moreover, developing software for such games became easier due to the availability of simple programming languages for beginners and easy to use software frameworks for game design.

This paper addresses the possibilities of designing hybrid board games and discusses hardware and software implementation aspects for creating a hybrid board game. For the motivation we build upon the fact that there is already a strong market for analog board games and we discuss the augmentation of such games towards a hybrid board game. While there is also the possible for a transition from pure computer games towards hybrid board games, we assess this to be the less frequent path and, therefore, consider a discussion of advantages/disadvantages between digital games and hybrid board games out of the scope of this article. In the last part of the paper, the creation of hybrid board game prototypes from scratch is addressed by the example of a game jam.

Properties of hybrid board games

When designing a hybrid board game, there are many possibilities for parts of a game that could be implemented as the digital part. Table 1 gives an overview on different aspects.

A video introduction of rules or an electronic rulebook would be the easiest form of adding a digital component to a board game. This marks also the least intrusive way, since it leaves the rest of the game as a pure analog board game. Still, such a digital component might improve games with complex rules significantly in terms of startup time and gameplay.

Overseeing gameplay and rule compliance can be a difficult task in analog board games. Apart from the fact that a player might cheat intentionally, some game mechanisms are prone to mistakes in counting, missing parts of a game situation or forgetting an update. For example, the game *Crude: The Oil Game* (St. Laurent 2004) has a mechanism, where certain double dice configurations trigger an update of the economy phase card. This action is in addition to the usual effects of dice in the game and is, at least among unexperienced players, a frequent part of the game that is forgotten. Implementing such a mechanism in a digital part could relieve the player from a double update and ensure that it is always handled correctly. A similar aspect is the updating of the game state which can be a cumbersome task for the players. These chores could be easily translated into computer logic, however, those chores could also be an essential part of the social interaction of the game (Xu et al. 2011).

The digital part could be also used as random number generator. Some games require sophisticated random functions in order to be correctly balanced, which is usually solved by non-standard dice, multiple dice, a dreidel, or spinners customized for the game. In a computer program, a random function can be easily implemented with arbitrary complexity. Furthermore, the digital solution can hide the underlying mechanism from the player, if the game design involves the assessment of a random chance.

Some games feature unexpected events, which are brought into the game by drawing a card containing information that has to be read out loud to the other players. A well-known example for such a mechanism are the chance and community chest stacks in *Monopoly* (Magie and Darrow 1935). Moving the content of such unexpected events from a card stack into a computer program reduces the limits on different events and description length. By adding generative content, the unexpected events could be even made truly surprising, while keeping the narrative of the game.

Some mainly cooperative games like role playing games require an antagonist, typically played by a game master. Notable exceptions are pure cooperative games like *Pandemic* (Leacock 2008) or *Game of Clones* (Fuchs et al. 2020) where the complexity of the antagonist emerges from a set of simple rules. For both cases, the implementation of the antagonist's turn could be automatized digitally, leaving a clear separation between "good" (the players in the analog domain) and "evil" (the computer).

As discussed by Frapolli, Hirsbrunner, and Lalanne (2007), the modes of communication in analog games are limited when it comes to mediated secrets or private communications. Systems with networked digital devices could augment the communication possibilities with respect to this issue.

The pace of a board game is often determined by the speed of the players, which may vary a lot and can lead to discussions. As a consequence, a certain play duration is hard to predict or to guarantee for many analog board games. As discussed in (Elmenreich 2019) game length could be a hindering factor towards enjoying games. Games featuring a countdown or a clock defining turn time could reduce the playtime for one game significantly. The most prominent example is the usually slow-paced game *Chess* which was made significantly faster in its variant *Blitz Chess* by utilizing a chess clock with a few minutes of time budget.

The size of the game world is naturally confined by the amount of game materials and the size of the table to put the game board onto. A few exceptions are RPGs without a direct mapping of game world to game board. Moreover, the contents of the game world can be only varied by re-arranging existing elements (which is nicely exercised in *Die Siedler von Catan* (Teuber 1995)). These limitations can be overcome by generating the game board in the digital part. In this case, the players need suitable devices (tablets or mobile phones) that can replace the game board or become part of the game board.

A final aspect is the production cost of the game, which are heavily affected by the amount of game materials. In contrast, pure digital parts come with zero marginal cost, that means additional copies don't affect the production cost once the digital parts are finished. This becomes especially a factor for digital parts that are provided as download without the production of a DVD or similar data carrier and run on the players' own hardware. Note that making parts digital should not be overdone to keep the character of a board game. In addition, the interface between the analog and digital part should be simple. An excellent example for a well-defined interface is given by Ravensburger's Family Game *Schnappt Hubi!* (Bogen 2012), where a few buttons on a dedicated hardware device are sufficient to keep synchronization between analog board and virtual game world data.

Aspect	Implementation in analog game	Implementation as digital part
Introduction to rules	Section in rulebook; either read by one player out loud, explained later or read by every player separately	Video tutorial that can be watched together, electronic rulebook
Observance of game rules	Self-discipline, watching others	Automatic rule enforcement
Updating game state	Manual by each player or a dedicated player	Done automatically by a program
Introducing randomness	Dice, spinners, or picking cards from a shuffled stack	Program calculates randomized result using a random number generator
Unexpected event	Prepared information is read out loud, content limited to a card or similar	Computer program presents contents, no significant limit on media types and length

Antagonist	Played by a game master or an opponent team	Simulated by computer
Secret communication	Passing of prepared cards with limited answers	Can be supported by a secret channel on smartphone
Keeping game pace	Self-discipline or clock devices	Computer program can set a pace
Size of game world	Defined by amount of game material and size of table	Game world can be virtually extended to arbitrary size
Variation of game board	Board is provided in parts that can be assembled in different ways	Game board can be generated in an arbitrary way
Price of game	Trade-off between amount of game materials and production cost for game	Zero marginal cost for digital part when hardware is provided by user

Table 1 Possibilities for augmenting an analog board game

Hardware platforms

Depending on the intended task for the digital part, several hardware platforms could be an option.

Standard PC or laptop

A PC or laptop typically provides a large screen and a possibility to issue music and sound. While there exist different operating systems (Windows, Linux, Mac OS) the provided features are nearly identical, which are networking capabilities, large working memory and disk space, fast processor and good support of various programming environments. As standard user interface a keyboard and mouse (or trackpad) is provided, while the system can be easily extended with additional hardware (e.g., camera, fingerprint reader, joystick, buzzer) via USB and wireless interfaces. Disadvantages are size and cost. Mobility, especially in the case of a PC is very limited. Therefore, it might be cumbersome to move a PC to the game table to play a hybrid game. In addition, while the current penetration of PC and laptop systems is about 40 percent in developing countries (Holst 2020a) and over 80 percent in developed countries (Holst 2020b), there is an ongoing trend of declining PC sales in the last years (Titcomb 2016).

Mobile platforms

Mobile platforms encompass mobile phones and tablets. Especially mobile phones have a high penetration so that it is safe to assume that a group of players would have at least one such device. Both, mobile phones and tablets provide input features for location, acceleration and position, allowing for challenges like balancing or moving the device. The screen size of a mobile phone is considerably small, which can be an advantage (fitting onto the game board) or disadvantage (having problems to display all relevant

information). Due to security restrictions and walled garden concepts an app usually can only be easily installed when it is available in the app store. Unfortunately, adding an app to the app store can be costly and cumbersome. An alternative is the use of software that runs in a web browser.

Customized embedded platforms

If the game interface requires specific features such as motors, specific button or lamp layouts, an implementation with an embedded platform is the most feasible. Possible platforms are the Arduino series providing a suite of different sizes and capabilities or other single board computers like calliope Mini or the Raspberry Pi. The latter comes with impressive capabilities for computation, multimedia tasks networking, and storage and can be connected to a standard TV as output device.

Peitz, Eriksson, and Björk (2005) discuss augmentation of games with electronics on the example of game tokens with RFID tags.

Another possibility are dedicated installations or even small robots that would interact with the players physically. To enhance such a design, customized cases and manipulators can be produced using 3D printing technologies.

Consumer electronic devices

Consumer electronic devices such as smart TVs, DVD/Blue-ray players or audio systems can host a video or audio sequence that guides through the game. The DVD specification supports also the implementation of interactive games that are played with the remote. While such approaches have been used in previous hybrid tabletop games (for example in *AtmosFear* (Clements and Tanner 2004)), the effort to create a playable image and the dependence on a particular device make this option nowadays less attractive.

Designing the software part

In pure computer games, the multimedia content of the game typically requires a huge effort in the game design. For a hybrid board game, where the visible haptic parts of a game stay in the physical domain, the digital part is significantly reduced. Tasks like bookkeeping of players' stock are easy to implement in any programming language and even the multiplication of such a task to a high number of entities is straightforward to solve in a computer. The major challenge arrives from the interface to the player and/or the analog board. Using specific hardware like a touch sensitive game board, an RFID token or a camera system with dedicated image processing can require a huge implementation effort. Furthermore, the success of a user interface depends also on the surrounding elements. The same implementation of a digital game part might be successful in a setting where the interactions and user interfaces harmonize the analog design while failing in a setting where the analog design does not match. Moreover, testing procedures could be more complicated for software of a hybrid board game since an integration testcase would require playing the full game including the analog part, which makes it impossible to apply automated software tests.

In some cases, the selected hardware platform forces the choice of the programming language (or at least reduces the options significantly). For example, the Arduino Platform is typically programmed in C or Assembler and the Calliope Platform uses the programming language Swift. The majority of platforms, however, leave several options for the software design.

Dedicated software platforms

Anyboard (Mora 2016) is a platform specifically target hybrid board games. It aims at providing tools for mapping traditional board game interaction to a hybrid medium. It provides a library in JavaScript to support coding of games and interacting with hardware in form of augmented game tokens. The Anyboard software is available as open source on Github[1].

Game design engines

Game engines like Unity 3D, Unreal Engine, Game Maker Studio, etc. are designed to provide easily accessible features to display game graphics, implement sprite objects with physics and collision detection, integrate game sounds, etc. While those features are not of prime interest for the digital part of a hybrid game, those game engines are still chosen for two reasons: First, they provide multi-platform support, so a game can be exported for web, PC, or mobile platform without additional effort. Second, a game designer might be already familiar with a particular game engine and, therefore, decides to use it to make a simple digital part of a game.

Standard programming languages

Another possibility is the implementation in a programming language supporting the minimum requirements for the task. If the digital part should do mainly some bookkeeping in lists, the resulting program will not need sprites and might not even need a graphical user interface. In this case, programming languages like Python, Java, Javascript, C#, Lua, BASIC, etc. are an option. For teams without an experienced programmer, beginners' programming languages could be the best approach. For example, Scratch or Snap! consist of simple, block-based elements that can be assembled into a program in an online editor. The resulting project can be hosted on the Scratch or Snap! webpage online so that the people playing the game would need only a device with a web browser to use the program.

Case studies from a hybrid board game workshop

As a pre-conference event of the Future and Reality of Gaming - 13th Vienna Games Conference, a hybrid board game workshop was organized at the University of Klagenfurt on October 4-5, 2019. The workshop scheduled a registration for participants and then two presentations. The first presentation introduced to game design and hybrid games while the second presentation featured a short tutorial introducing game programming tips. The tutorial was specifically aimed at people with no or low programming experience. The remaining part of the workshop was organized as a game jam: after announcement of the topic, “Sustainability”, participants were assigned to random groups for brainstorming game ideas. This marked also the end of day one. On the beginning of the second day, all game ideas were presented in short pitches. After the pitch presentations, the participants could decide to join a team for making one of the pitched games. After this phase, five teams with between two and six people had formed and started working on implementing their game ideas. Participants were provided craft materials and tools that they could use for making their analog game materials. Computer hardware was brought by the participants themselves.

[1] https://github.com/Anyboard/anyboard

Workshop results

Considering that the teams had only one working day to elaborate a game prototype, the resulting games looked very promising. All 5 teams finished with presenting their games at the end of the workshop. The resulting games had the following characteristics:

The game *HexaChess*[2] is based on a hexagonal board with triangle-shaped tiles. Two opponents are trying to capture the enemy pieces, where the movement possibilities vary based on markings on each field. The digital aspect is brought in as a clock timer application that manages the players' time budget and urges the players to turn the board every now and then. The sustainability aspect is considered at a meta-level, since the game is designed in such a way that it can be produced locally from simple materials.

The game *Rock-Paper-Scissors*-Pollution features a game map with a digital part implementing conflict rounds in a rock-paper-scissors mechanism. For this game, the digital part contained the main elements of the gameplay. Unfortunately, the game prototype and software had not been published.

The game *Bigger Picture Space Ship* has a strong focus on the analog part. As shown in Fig. 1, the game features magnetic game pieces that form parts of a space station. The slim digital part contributes interaction and random number generation. The gameplay requires to balance the resources in a way so that the operation of the space station was sustainable.

Fig. 1 Analog parts of the game Bigger Picture Space Ship

The game *Environmental Auction* provides a gameplay where a player has to collect a proper set of power plants. The original game has a board and differently colored game chips that has to be collected. In a post-jam version of the game, *Energy Auction*[3] these elements had been integrated into the digital part of the game, providing a mostly digital game in the end, with the auction being the only offline element.

The game *Seawatch*[4] addresses the situation of people in distress in the Mediterranean Sea and the problems in getting accepted into a harbor with refugees on board. The game, depicted in Fig. 2, features typical elements like stocking and movement on a

[2] https://firetotemgames.itch.io/hexachess
[3] https://csdb.dk/release/?id=184990
[4] https://csdb.dk/release/?id=185191

printed map with hexagonal tiles. Updating of stocks like fuel and food has to be done by the players manually. In contrast, all events and actions that are not under the control of the player or that could not be foreseen are managed by a computer program. The chance of being accepted into a haven is based on a hidden random variable that is defined at game start by the computer. Thus, part of the game is also to find out which harbors are more open towards bringing in saved people.

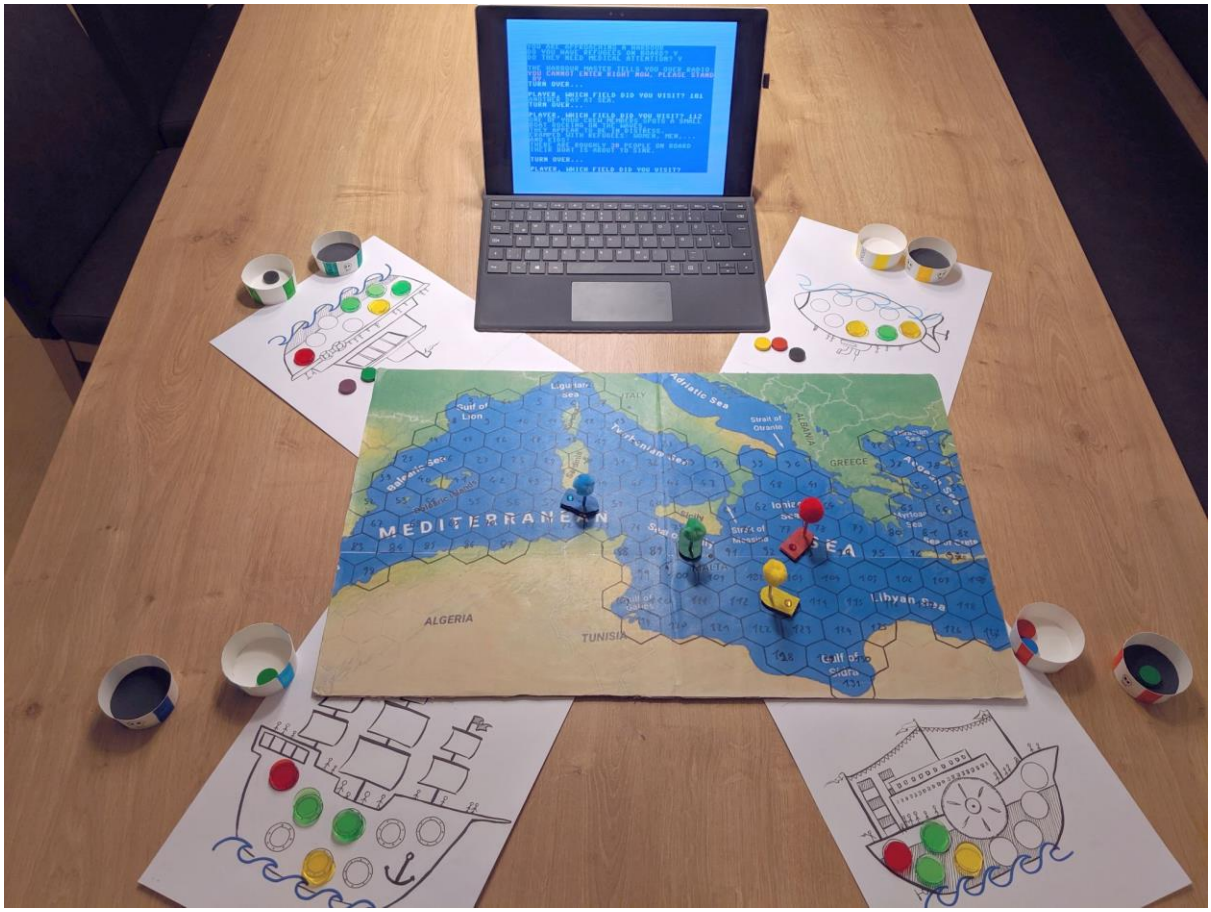

Fig. 2 Game elements of Seawatch

Summary and Conclusion

A typical board game offers many aspects where a digital part could be used to improve gameplay or to relieve the player from cumbersome tasks. To keep the character and social interaction of a board game it is advised to find a good balance between the two parts. The current penetration of computers and mobile devices in western households allow for games that rely on the players' hardware. In addition, existing game engines and software frameworks support rapid development of the software part. Experiences with a short workshop have shown that prototypes of hybrid board games, including the digital part can be created by a small team in a single day.

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