

ENHANCED VALUE BENEFIT ANALYSIS OF GAME FRAMEWORKS AS A TOOL FOR DIGITAL SERIOUS GAME DEVELOPMENT

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Abstract

When creating a digital serious game the major challenge arises from the selection of a game engine, one which optimally supports the right balance between engagement and learning.

The approach presented in this paper is based upon a generic model of a value benefit analysis. The model is enhanced by a matrix which encodes the evaluation of a game framework not only by its value for the individual game design needs but especially for the individual didactic value. The model enables decisions on subjective factors for this multidimensional evaluation issue. It does not present a tool to generate an impartial general ranking list of game frameworks for serious games. It is a tool for serious game developers to have a subjective individual list of game frameworks fitting their individual needs of technical requirements and didactic motivation. The basic concept and strategy behind the approach are presented as well as an application example.

This paper presents and discusses a hierarchy of general criteria for developing a serious game which can be used to evaluate a framework within the model. The criteria are divided into main and interleaved sub criteria. The paper also discusses the weighting of criteria and the used cardinal scale for criteria and weighting. Finally the paper comments on the matrix which will consider the didactic needs.

With the described approach developers of serious games will have a workflow on how to find a suitable game framework with regard to the defined game design and didactics.

Keywords: serious games, value benefit analysis, didactics, e-learning, technology-enhanced learning.

1 INTRODUCTION

Serious games are one of the major trends in e-learning. The so called game-based learning attempts to exploit the users' intrinsic motivation to use (play) the e-learning system (game), and to simultaneously impart new or updated knowledge. When creating such digital serious game the major challenges are (1) to ensure the right balance between engagement (as defined by Prensky [1], see Fig. 1) and learning as well as (2) how to find the best fitting underlying game framework or engine. Whereas the former is of theoretical nature and involves the actual game design and specification the latter essentially provides the user interface and is the limiting technical factor. The selection of a game framework can have severe implications on the technical implementation and on the user experience of the serious game.

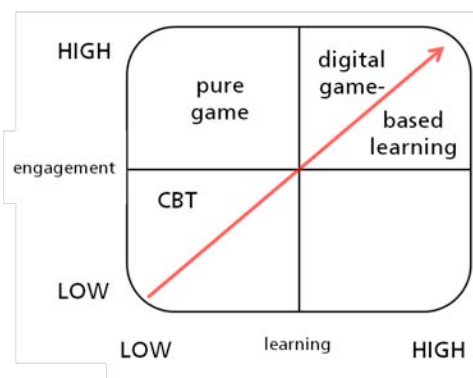


Figure 1: Balance between engagement and learning (based on [1])

Typically the learning objectives and the game design concept are defined at first then a game framework is chosen which optimally supports the specifications and requirements. However, this decision process is not standardized neither exist guidelines on how to optimally choose the best fitting game framework. This paper presents a workflow and a toolset for the optimal selection of a game framework for your serious game development. We present a formalized strategy how to align your learning objectives and your game design requirements with a game framework. The result is a weighted evaluation matrix which encodes scores for the didactical requirements aligned to game frameworks. Based on this matrix a global evaluation index value can be derived to find the best fitting game framework with the optimal support for the right balance between engagement and learning.

The proposed workflow and toolset is applied to an ongoing research project in the application domain of image interpretation. Image interpreters not only must be able to recognize various complex objects but they also require background knowledge for the correct and sound interpretation. Different sensor and imaging parameters, a high variety in appearance of objects around the globe and time pressure create a challenging and demanding working environment. An additional difficulty arises with the use of complex imaging sensors, for instance radar image sensors. Special training and substantial experience are required in order to be able to identify objects in radar images. To train SAR¹ image interpreters various strategies exist. One of them is to ease the training with digital serious games.

2 RELATED WORK

For the development of digital video games a wide variety of game frameworks exists, for instance see the 3D game engines database on DevMaster.net [2]. In the context of digital serious games for learning and training such game frameworks can be used. Most research focuses on the evaluation of a particular game engine for its use in a specific application scenario or a specific learning context, for example in medicine [3]. Primarily the learning outcome is of interest but not why the used game engine has been selected. However, as of today no formal survey or study could be found which game engine matches which requirements best.

Similar research to our proposed methodology has been presented by Pedridis *et al.* [4]. They give a methodology how to select a game engine with focus on high fidelity for their use case high-fidelity model of Ancient Rome. Fu *et al.* characterize various technological aspects as well as the training process [6]. They introduce a set of evaluation criteria with which game engines can be evaluated. Also in this line is the work of Freitas *et al.* who present an evaluation methodology for supporting the development of specified learning activities in virtual worlds, in particular for Second Life [5]. Their proposed methodology is oriented at their so called 'Four Dimensional Framework' which provides them with a structured approach to the syntheses and analysis of their research findings.

To create a methodology how to find the best matching game engine we propose to call on the principles of the commonly known cost-benefit analysis, and in particular the value benefit analysis [7][8]. Instead of actual costs in the monetary term we are looking at the added value of a particular game engine regarding the specified evaluation factors.

3 VALUE BENEFIT ANALYSIS

The proposed workflow and evaluation methodology for a specific serious game project consists of two main parts: (1) the value benefit analysis of game engines, and (2) the application of didactic requirements. In the following we focus on the value benefit analysis.

In this first step the game engines are evaluated regardless the didactic requirements. We do not consider the didactic requirements as this vital part cannot be viewed as some additional criteria concerning the evaluation of game frameworks. They are substance of the next section of this article.

The proposed analysis model is based upon the procedures of a value benefit analysis. This procedure is often used as an equivalent to the cost-benefit analysis (CBA). The CBA implies the enumeration and evaluation of all relevant costs and benefits [8]. However we do not want to put the focus just on costs versus benefit. We want to facilitate the decision according to physical, monetary, economic but mostly on subjective emotional factors, so called "soft" factors. Using our model for the value benefit analysis will lead to an individual subjective ranking list of suitable game engines for our specific serious game project. It will not be a general ranking list one could transfer to other projects.

¹ SAR is an acronym for Synthetic Aperture Radar.

So if in a resulting list Game Framework A is better than Game Framework B, it does not mean that this is the case in general.

3.1 Specification

At first we established a target tree which incorporates all criteria useful for the evaluation of game frameworks. It is divided into main and interleaved sub criteria. It presents a hierarchy of general criteria for developing a serious game.

Without loss of generality the presented criteria subset aims to be as general as possible for the development of serious game projects. Of course, for individual project needs this target tree has to be adjusted. In particular criteria which are not required should be removed to avoid redundant effort and to reduce overall complexity. The definition of additional sub criteria must be independent from all other criteria in order to avoid unintended interference. In general, the final target tree should contain only criteria which are considered significant for the specific serious game project.

To evaluate a game framework each leave criteria in the target tree is rated. This rate is called target rate. We propose to use a cardinal scale with number of points ranging from 0 to 10. This figure implies the achievement rate for the specific criterion (Table 1). Zero points mean that the target criterion is not achieved at all; 5 points mean that the target criterion is partially achieved; 10 points mean that the target criterion is fully achieved. In order to attain a general understanding of the rates our model provides a detailed description of ratings for each criterion.

Table 1: Target rate meaning

Target Rate r	Meaning
$0 \leq r \leq 3$	bad – target criterion is not achieved
$4 \leq r \leq 7$	average – target criterion is partially achieved
$8 \leq r \leq 10$	good – target criterion is fully achieved

Our model uses a relatively sophisticated rating scale because of the huge amount of possible game framework alternatives. By providing this scale it is easier to distinguish between the alternatives and not to risk equal ratings of different alternatives.

Each and every criterion must be rated. The model does not work properly with unvalued criteria. If it is not possible to rate a criterion the target tree should be adjusted instead. The found target rates are not weighted.

A general weighting of the criteria is not suitable as this is heavily dependent on the requirements of the specific serious game project. Such a weighting is an individual process and cannot be proposed in general. However regarding the didactic requirements we propose to focus on certain criteria. This will be described in section 4.

The weighting applies to the target rate of each criterion. The subjective individual weight will be multiplied by the target rate resulting in the target value.

The value of benefit for the evaluated game framework results in the sum of all target values. If necessary the model can easily be altered in adding weights on the main criteria or on each node of the target tree as well.

We propose a weighting of the criteria on a cardinal scale ranging from 1 to 10. This figure implies the individual significance of the criterion. One point means 'unimportant'; 5 points mean a 'relative importance'; 10 points mean 'essential'. Weighting a criterion with 0 points mean it is not significant at all and should be withdrawn from the target tree. The weight is normalized to 1 before it is applied to the target rate.

3.2 Criteria Parameters

Table 2 lists the target tree of our proposed value benefit analysis. As stated before table 2 lists all criteria we think are suitable for most serious games projects. It is necessary to adjust the target tree, for example when it is a serious games project in a non commercial context. In this case the criterion licensing type should be withdrawn.

For our serious game in the application field of image interpretation we made just slight adjustments to the target tree. We defined one show stopper criterion, licensing type. A show stopper criterion renders the whole value benefit result as 0, i.e. this game framework is not considered any more, regardless of all other resulting target values. Most serious game projects are of a commercial nature, even in research projects [9]. Therefore this definition defines it as fatal when the type of license prohibits commercial use.

Regarding the licenses it is necessary to distinguish between the different versions of licensing within each game framework. There are for example licenses with or without support which normally influences the criteria support and cost [10]. In order to keep the criteria independent it is essential to regard each license version as a separated game framework alternative. For example, in our serious game project we had to distinguish between multiple different license versions of Unity, as there are three manufacturer support options (none, premium, enterprise) [10].

Table 3 gives an example description for the target rating of the criteria licensing costs and licensing type. It shows the definition of our show stopper criterion as well. Our workflow provides such descriptions for all criteria of the target tree. When additional criteria are added to the tree it is mandatory to add respective descriptions.

Table 2: Target tree of game framework criteria

Main criteria	Level 1 sub criteria	Level 2 sub criteria
1000 Costs	1100 License Costs	1110 Licensing Costs
		1120 Licensing Type
2000 Documentation	1200 Hardware Costs	
	2100 API Specification	
	2200 Tutorials	
	2300 Example Projects	
3000 Support	3100 Manufacturer Support	
	3200 Community Support	
4000 Development	4100 Supported Platforms	
	4200 Supported Programming Languages	
	4300 Supported Graphics APIs	
5000 State / Stability	5100 Maturity	
	5200 Activity	
	5300 Market Penetration	
6000 Features	6100 Framework Features	6110 Object Oriented Design
		6120 Plug-In Architecture
		6130 Tools & Editors
	6200 Game Features	6210 Networking
		6220 Audio/Sound
		6230 User Interface
		6240 Physics
		6250 Artificial Intelligence
	6300 Graphic Features	6310 Lightning & Shadows
		6320 Textures
		6340 Meshes
		6350 Game Rendering
		6360 Special Effects
	6400 Genre Features	
7000 Handling	7100 Degree Of Freedom	
	7200 Operation	
	7300 Workflow	

Table 3: Example description of target rating

Nr.	Target	Target Rate		
		$0 \leq r \leq 3$ bad	$4 \leq r \leq 7$ average	$8 \leq r \leq 10$ good
1110	Licensing Costs	Licensing is very expensive and/or requires high royalty fees (i.e. high percentage of project budget/revenue).	Licensing costs are reasonable. There are no or only one-time mandatory follow-up costs.	Licensing is free or requires only a small amount (<\$2.000). There are no follow-up costs.
1120	Licensing Type (fatal flaw criterion, 0 or 10)	The license type does not allow the development for commercial use or infects the source code.	-	The license type does allow the development for commercial use and does not infect the source code.

At this point our workflow model can be used by developers for entertainment games as well. To cover the didactic requirements which come along with serious games we developed a matrix described in the following section.

4 GAME DESIGN VALUE BENEFIT MATRIX

As stated before we identified seven main criteria for the game framework evaluation. Besides technical indicators like development platforms and technical features also non-technical aspects are taken into account.

Besides the general but most determining project environment with its triple constraints scope, cost and schedule – nowadays extended to at least six competing factors according to PMI [11] – the capabilities of the game framework aligned with the educational requirements provide the basis of the planned serious game. The practicability of educational requirements within a game framework reflects more or less with the technical capabilities and features whereas the aspects of costs, documentation, support and development mostly correspond to the project environment and underlying conditions.

In Fig. 2 the concurrent categories project environment (A), game framework (B) and educational requirements (C) are shown. In our approach we combine both technical and economical factors of the value benefit analysis with the educational requirements of the serious game to form a matrix. The layout and content of the matrix will depend on the given (project) scenario and can be used as a decision tool. In regards of the educational requirements the criteria must also be selected.

These economical constraints influence the weights of the game frameworks criteria and thus the evaluation scores.

4.1 Educational Requirements

As a detailed explanation of all possible indicators would go beyond the scope of this paper and the selection should depend on the type of serious game we introduce a sample set for general understanding. The level of detail of a criterion might be different and might even contain recurring sub-categories of other educational requirements but in different scope.

In the following three sample educational requirements are presented: player enjoyment, level of realism and story-telling.

Developing a serious game should imply '*player enjoyment*' first. It can be assessed by a game flow matrix including the elements concentration, challenge, player skills, control, clear goals, feedback, immersion and social integration [12].

The quality of 'reality' from a didactical point of view implies not only the *level of realism* in terms of e.g. computer graphics and its portrayal of the real world but also level of implementation of laws of nature. Especially mathematical and physical principles like geometry, appetite or earth's

gravitational pull to name but a few. A paragon for reflecting some of those physical principles is the game *Crayon Physical Deluxe* [13] “in which you get to experience what it would be like if your drawings would be magically transformed into real physical objects.” [14] The players are creating their own worlds by ‘painting’ objects with the mouse – e.g. lines and blocks forming a ramp for the ball to proceed. It should be noted that this game also serves as a good example that a high degree of realistic computer graphics isn’t necessarily needed in terms of motivation and immersion. Furthermore especially an ‘ultra-realistic’ approach for graphics (not so much for sound indeed) might create problems within the game and their players feeling not comfortable with it [15]. This also depends on our empathy and is well described by the theory of *The Uncanny Valley* by Masahiro Mori in the 1970s. Depending on the educational needs these requirements have to be taken into account with sub-categories of ‘features’ of the game framework.

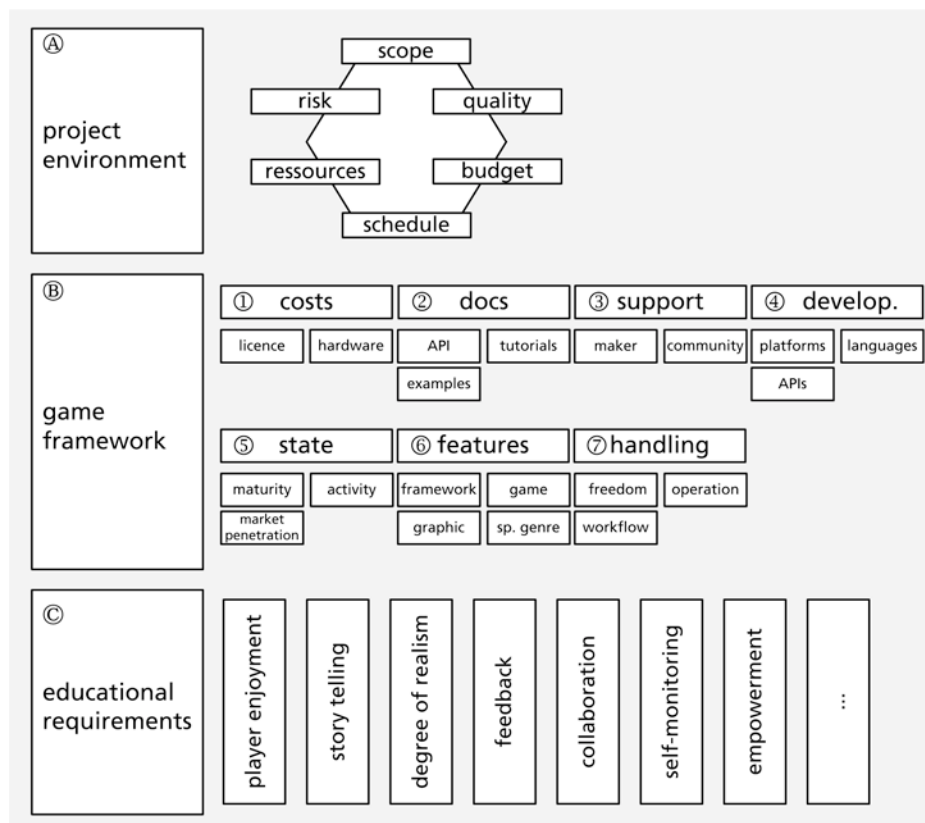


Figure 2: Criteria of game framework analysis

The dimension ‘*story-telling*’ reflects the didactical type of game and which story it inherits. For example a story which should be wrapped into some kind of point-and-click or *Wimmelbook* [16] implies a different setting as an exploration of a great unknown map scenario. Therefore this dimension is connected to ‘features’ of the game framework in general and furthermore with ‘graphics’ and ‘special genre’ in detail.

For our serious game application we identified the educational requirements *player enjoyment*, (as we want to do more a game than a simulation), *storytelling* (for a campaign setting), *degree of realism* (in terms of image interpretation) and *feedback* from the above.

4.2 Evaluation & Interpretation

To evaluate how the game frameworks work together with the established educational requirements the evaluation matrix is built. The following describes the procedure how to build the matrix and how to calculate the overall evaluation score.

The basic idea is to create a grid with mappings of educational requirements to game framework scores and use that mappings to calculate the overall evaluation score. The matrix rows represent the educational requirements; the matrix columns represent the game framework scores. For each cell in

the matrix a composite score is calculated and all these scores are summed up to yield the overall evaluation score.

Each educational requirement must be assessed to each game framework criterion. For each educational requirement this yields a one-dimensional list of binary values $\{0,1\}$ where each value declares if a requirement is relevant for the corresponding game framework criterion. For multiple educational requirements this yields a two-dimensional matrix. This matrix $S \in \{0,1\}$ can be seen as a mask where zero-values mean 'irrelevant' and ones mean 'relevant'.

To apply this mask S a second two-dimensional matrix for the game framework scores $C_j, j = 1 \dots m$ is needed. This matrix is built by row-wise repeating n -times the one-dimensional game framework scores, where n is the number of educational requirements $R_i, i = 1 \dots n$. The evaluation matrix E is the result of the binary operation (Hadamard product) of the value matrix V and the mask S where each element ij is the product of elements ij of the original two matrices:

$$E = V \circ S = (v)_{i,j} (s)_{i,j} \quad i \in \{1, \dots, n\}, j \in \{1, \dots, m\}$$

To calculate the overall evaluation score q , all the 'visible' values after applying the binary mask are summed up. This value q is then normalized by the total number of elements ij as in

$$q = \frac{1}{nm} \sum_{i=1 \dots n} \sum_{j=1 \dots m} (e)_{i,j}$$

For an example see Fig. 3. For a set of 3 game framework criteria (C_1 - C_3) and 3 educational requirements (R_1 - R_3) the matrix V contains 3 times the game framework scores row (3×3 matrix). The mask matrix S contains the 'punched holes' for each educational requirement in relation in each game framework criterion. These two combined yield the evaluation matrix where the cells are 'visible' for which the 'punch holes' in S have the value 1. In the example the game framework evaluation produced the scores 0.35 for $C_1 =$ 'license costs', 0.78 for $C_2 =$ 'graphic features' and 1 for $C_3 =$ 'handling and workflow'. One could assess the education requirements 'level of realism' as important for C_1 and C_3 , 'feedback' as only important for C_3 and 'story telling' as important only for C_1 . The maximum evaluation score would be 1.0 when all game frameworks criteria are perfectly met and all educational requirements are relevant. For this example the overall evaluation score is $q = (1 + 1 + 0.35 \cdot 0.35) / (3 \cdot 3) = 0.3$.

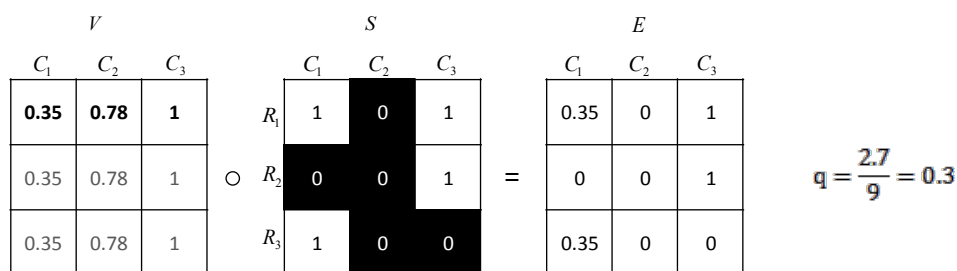


Figure 3: Example for evaluation matrix and relevance mask

This overall score q allows to rate the suitability of the chosen game-framework and its parameters C_i combined with the educational requirements (see R_i) of the planned serious game compared to other possible game-framework solutions.

5 CONCLUSION

We presented a toolset and a workflow to find a suitable game engine for the individual needs of a serious game project especially under the consideration of didactic requirements. We used this approach for our serious game in the context of image interpretation and it proved to speed up the evaluation process. So our workflow is a valuable improvement and simplification in the preproduction process of serious game development. To underpin this procedure model a complete list of educational requirements as catalogue is planned.

To generalize the presented methodology we propose to collect the masks which have been created for serious game frameworks and educational requirements. This could be done online in Web 2.0 approach. With the collection of multiple masks one universal' mask for the genre could be derived. This will be topic of future research.

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