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**STRATEGIES AND TOOLS TO ENABLE REUSE IN SERIOUS GAMES
ECOSYSTEMS AND BEYOND**

Ioana Andreea Stănescu

*"Carol I" National Defence University, 68-72 Panduri Street, Bucharest, Romania
ioana.stanescu@aldnet.ro*

Antoniu Stefan

*Advanced Technology Systems, I Tineretului Street, Targoviste, Romania
antoni.stefan@ats.com.ro*

Theodore Lim

*Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, Scotland, UK
t.lim@hw.ac.uky*

Jannicke Baalsrud Hauge

*Bremer Institut für Produktion und Logistik (BIBA), Germany
baa@biba.uni-bremen.de*

Robert Wendrich

*University of Twente, 7500AE Enschede, the Netherlands
r.e.wendrich@utwente.nl*

Gabriela Neagu

*Research Institute for Quality of Life, 13 Calea 13 Septembrie, Bucharest, Romania,
gabi.neagu@iccv.ro*

Francesco Bellotti

*Department of Naval, Electric, Electronic and Telecommunications Engineering,
University of Genoa, Via all'Opera Pia 11/a, 16145 Genoa, Italy
franz@elios.unige.it*

Abstract: *Software ecosystems are defined as collections of organizations that are related through software or a software related concept. Within such ecosystems, reusability is fundamental to software sustainability and cost-efficiency. Design for reusability brings the technical promise of high quality software that emerges from clean design, fitness for a purpose and a low defect count. This ensures the software is extensible to cater for or modifiable for different pipelines, data and purposes. Serious Games (SG) software projects are an example of software ecosystems that have been known to consume considerable resources, yet deliver sub-standard and expensive products. From an educational perspective, the accessibility of reusable, open components repositories for SG development would provide far greater benefits. SG researchers, developers and implementers can adopt reusability to create a gateway to reusable SG assets for the SG community. This would facilitate sustainable models, class libraries, organizational structures, and knowledge to improve SG design and fit for purpose. For SG reusability to reach its full potential this effort should not address exclusively the SG ecosystems but cross the boundaries of other disciplines to establish its impact. Under these premises, the authors consider the development of a Serious Games Reusability Reference Point (SGREF) to assist the SG community and support trans-disciplinary initiatives.*

Keywords: *serious games; reusability; SGREF*

I. INTRODUCTION

Software ecosystems are a blooming research field [1]; their evolution begins from community building initiatives that demand reengineered strategies and dynamic models to nurture efficient, qualitative integration and collaboration [2]. The extensive growth of the Serious Game (SG) community in recent years [3] is such an example that calls for new strategies and tools to support a robust ecosystem development.

From a community perspective, success depends vastly on a plethora of built-in abilities:

- be timely and correctly informed on emerging research findings and market evolutions;
- overcome the information overload in the online community, as well as other communities that relate to the core domain;
- adopt, develop and apply sustainable standard- and interoperability-based practices;
- identify successful patterns in design, development, and deployment that fundament reusability;
- establish a common terminology at community level;
- enable defragmentation between research and industry;
- stimulate innovation and creativity within the community and beyond.

Such abilities enable performance, efficiency, cost reduction, and quality control at community level. This strengthens the ecosystem and increases its dynamism of the relationships within. In order to develop and enhance these abilities, the collective individual and organisational knowledge should extend beyond the community. To achieve this level of competency and for all 'residents' of the community to benefit from it, is a considerable challenge.

A community-based approach brings forward new opportunities under these premises. As with crowdsourcing [4] it inherently provides an encyclopaedic overview of the resources residing within a community and beyond, thereby exploiting every dimension and offering. This paper addresses the strategies and tools that could be implemented at an ecosystem level to explore new modalities to facilitate qualitative, efficient research, development and deployment (RDD) of the next generation of educational media. It identifies challenges that coexist in the SG ecosystem lifecycle from a development perspective and advances initiatives that aim to provide assistance not only to individuals directly involved in SG RDD – researchers, designers, developers, teachers, trainers, etc. -, but also for policy makers, adopters such as entrepreneurs, businesses, etc.

1.1 Challenges

In digital game-based learning and teaching, designers and developers creating the products, as well as teachers providing them to students are faced with many challenges:

a) Complex design and development processes

The design and development of an SG project entails distilling decades of concepts, methods, technologies, pedagogies, as well as specific knowledge related to the educational domain that is targeted (math, languages, science, economics, military, history, health, etc.) to something that is digestible, useful, and applicable. Moreover, it requires a very diverse skillset that includes understanding not only the learning theory, the game theory, and technology, but also context, people, businesses and so on [5]

b) Heterogeneous deployment environments

The requirements and the particularities of possible implementation scenarios have to be considered. Such requirements lie not only at the end user level (e.g. skills required to play an SG; the digital natives expect high quality and increased performance not only in commercial games, but also in SGs), but they relate also to specific limitation of SGs (e.g. the lack of customization options) or deployment environments (e.g. lack of adequate hardware and software resources; lack of best practices in a certain field; SGs not integrated into the curriculum).

d) The negative effect of information overload

The Web is a powerful tool. Researchers can now search, sort, and filter SG projects to find the resources they need. Advances in information technology and communication has created a 'now' society; our ability to manage this information becomes more and more stretched [7]. In today's

information-driven economy, the ability to efficiently find, critically analyse and intelligently use information and resources is vital for competitive efficiency and profits. However, the massive exposition to this critical valuable resource leads to information overload with detrimental effects [8].

e) The need for creative and innovative SG products

Creativity has been credited as a critically important factor in the success of a company or of a career, as it is one of the major sustainable competitive advantages for companies and individuals [9]. Thus, within the SG area it is important to put forward strategies that foster the creativity potential, both at an individual level as well as a collaborative level. From product development, approaches for co-creative design have been known for decades and ensures early involvement of customers and other stakeholders. In addition, during the last two decades, communities that offer structured approaches for fostering collaborative development throughout the whole life cycle have emerged. Living labs is one of these collaborative community approaches. Both the development and the implementation processes of SGs rely heavily on creativity. Resources that stimulate creativity and innovation need to be collected and made available to the SG community members. New techniques that stimulate creativity and innovation need to be employed in order to fundament the development of a thriving SG community

c) Increasing growth of the SG community

The rapid growth of the SG research community in the European Union and worldwide has set the stage for a large diversity in serious gaming scientific research in terms of the application domains (military, health, business, engineering), scientific disciplines (psychology, computer science, social science), and development solutions. It is often argued that the large growth has created a problematically fragmented serious gaming community. The fragmentation makes it difficult to maximize contributions and successes, avoid overlap, enable resource reuse, as well as harmonized development efforts through interoperability [6].

1.2 Strategies

Among the relevant strategies that can be applied to nurture reuse within SG ecosystems, the authors highlight the following:

a) Enabling reuse, standardization, and interoperability of SG assets

Reuse

Reuse brings the promise of high quality software that emerges from clean design, fitness for a purpose and a low defect count [10]. It facilitates the transition from SG software projects that might consume significant resources that deliver ill-defined products that are over-sized, or fail to meet real needs to successful SG projects.

On one hand, reusability is the process of building or assembling SG project assets designed for reuse from previously developed projects. Properly understood, and deployed in the right context, reuse offers the opportunity to achieve radical improvement.

Previous research [11] has demonstrated reusability is not mutually exclusively to specific technical components. Even if software reuse has gained momentum, software patterns emerge as a manifestation of concepts, solutions, and best practices. Knowledge provenance should also be a concern of the SG community.

Reuse is fundamentally about learning (How do I encode stuff that is reusable and the information necessary to find and apply it?), memory (Where do I find something to reuse?), and problem solving (which is the reuse of previously acquired knowledge). While the goals of reuse are economic, its constructs are cognitive, and its mechanisms lie in the relative insignificance of intellect and technology. This perspective highlights the importance of education and training, management, knowledge acquisition techniques and the complementary techniques, and organizational structures and organizational roles that support knowledge dissemination.

Standardization

One of the main issues in the SG community, just as in the technology-enhanced learning domain, involves standards. Traditionally, international standardization translates into a series of benefits, such as: improvement in universal technical communication and mutual understanding; facilitation of international exchange of goods and services; removal of technical barriers to trade; transfer of technology; uniform terminology is created.

Standards enable interoperability between platforms from different suppliers and ensure compliance throughout the industry. Standards that relate to SGs aim to enable the reuse of SG assets across multiple environments and products. For some organizations, the primary focus might be on internal reuse of SG assets. For other institutions, developing and managing SG assets to be reused not only internally, but also by other external institutions can be of greater importance. Beside this perspective, developers today are still reluctant to making their resources open source. Moreover, adherence to standards does not ensure quality. Standards are focused on making things work well together. They do not seek to develop specifications for best practices in any given industry.

There is interest in the SG community both in depositing SG assets in repositories and in archiving them for reuse. Similar to Learning Objects (LO) SG assets should hold specific behaviour and interoperate with other SG assets. It should have its own characteristics yet exist in relationship with other SG assets. The metadata description of an SG asset should be able to reflect the behaviour of that asset. When selecting and reusing SG assets, either that SG asset can remain intact since it fits well with the new context, or that SG asset will need to be adapted. In the latter and more familiar cases, the problems that arise are not only technological in nature but also instructional. Metadata descriptions need to be sufficient to represent the behavioural nature of the SG assets including the learning objectives, where relevant. Furthermore, the level of granularity may pose a problem.

Reuse and management of reusable SG assets is one of today's main challenges. This is where standards are potentially useful. Certainly, much work is needed to refine and extend the research on how can standards positively impact the SG community, as to support a successful development and implementation of SG.

Interoperability

Wouldn't it be good not to start from scratch when developing a serious game? Wouldn't it be better to be able to integrate your serious game into the Learning Management System implemented at your university and automatically retrieve feedback on how well your students play a game? Wouldn't it be nice to be able to develop more at lower costs? Interoperability is one possible answer to these questions.

In the last decades, many discussions have taken place regarding interoperability and its role, and studies have shown the effects of "un-interoperability". Interoperability enables valuable connections, whether across processes, between people and information, or among companies. Providing SG interoperability support will help with decreasing complexity and better managing heterogeneous environment, while enhancing choice and innovation in the market.

Semantic interoperability aims to give IT meaning and represents a capability derived from the application of special technologies (such as inference engines, ontologies, and models) that infer, relate, interpret, and classify the implicit meanings of digital content, which in turn drive business processes, enterprise knowledge, business rules, and application interoperability [12].

The theory of interoperability aims to define the optimal level of interconnectedness and to layout the path for achieving it [13]. To do so, it has become necessary to develop a new lens for analysing how complex systems, components, and applications are connectable, as well as consider not only the promises, but also the drawbacks that come with increased connectivity. We need to balance the costs and the benefits of the connectivity we create, both in the short and long terms. While interoperability represents an opportunity for successful SG development and implementation, the role of the SG community is to assess how much interconnectedness we should aim to achieve among institutions, systems, and people, as well as lead to a clear understanding of the mechanisms – technical, organisational, or legal – through which interoperability can be achieved and optimized.

b) Strengthen the role of the online communities;

The usefulness and efficiency of the Web landscape depend on the ability of online communities to efficiently distillate information and facilitate access to valuable resources. The role of communities in managing information has become central. People have come together in alliances that have improved education, human rights, business ethics, and many other areas of public and private life. Community organizing, building the power of a group to change the world, is both an art and a science. Bringing groups of people into effective community organization takes skills and attention to many details and dynamics at the same time. It takes understanding of how groups work, why people join them, how to structure them, how to set goals, and rules, how to develop values and how to move people to action. Community groups can provide the intelligence needed to solve problems. A

community that focuses the resources and the energies and intelligence of many people who are close to the problem has the chance to actually solve problems [7].

c) Employ the potential of the Entertainment Game industry

Even if the academic community has opened up to games, game development and implementation remain a significant problem. Whether developers build their own game engine or license and modify an existing engine, that investment in time and resources remains a constant challenge. Content creation is a consistent budget item. Interoperability is implemented only partially and it does not reach its true potential. Quite often the targeted platform no longer represents a suitable choice. The development of serious games implies new challenges in terms of pedagogical approaches, game mechanics, assessment and metrics generating an even longer development cycle. What can SGs learn from the EGs? What reusable assets can be exchanged between the two communities for the benefit of both? Research has shown that there is a significant potential for asset and knowledge exchange between SG and EG communities [14].

Entertainment Games (EG) are fun, engaging and motivating; they offer an effective tool to create cognitive stimulation for an effective experience. Fun and enjoyment are very strong motivational factors and the primary method of luring a student into playing an educative game. But SGs lack fun and enjoyment. SGs are required to learn from the entertainment industry in order to develop a captivating and engaging game environment.

SGs and EGs usually differ in terms of budgets and versions that are released to the market [14]. Still both SGs and EGs rely on the innovative fusion of digital technologies and cultural creativity. Even if EGs and SGs answer to different objectives and performance criteria, there are significant lessons and important resources that SG communities can learn and adapt for reusability from the EG industry.

d) Enable cross-domain asset sharing (e.g. Bidirectional exchange of assets between the SG and virtual reality domains).

Collaboration between domains has always been fruitful. Connecting the SG field with other domains can only bring benefits to the field through reusable resources. Code and object reuse is a main concern for fast and efficient Virtual Reality (VR) system development and continual maintenance. Many commercial and academic VR packages offer reasonably nice abstractions for various functionalities needed by general VR systems such as the scene management, device integration, performance monitoring, object-orientation support, event processing, etc. In other words, software reuse is the functional level is reasonably well practiced and it opens new opportunities for reusability with the SG field.

At the same time, other domains can benefit of the outcomes of the SG community. For example, research has showed that CAD users spend more time in learning the CAD system than actually using it [15].

II. TOOLS TO SUPPORT REUSE

To enable SG researchers, developers, and implementers adopt and consolidate reusability as a way of working, it is necessary to create tools that act as gateways to reusable SG assets in the SG community and support the reuse of components, design patterns, class libraries, frameworks, cost models, knowledge, etc.

2.1 Reusability enablers

Reusable assets are at the core of reusability. By SG assets we understand work products of any kind, from any part of the software process. Since software work products capture knowledge that is important to the enterprise, they carry potential value. Reuse is a powerful means of exploiting that value-adding potential and imperative for the economical success within the SG development [16] Assets may be of a technical, knowledge or management nature, large-grained or fine-grained, simple or composite. They may have varying degrees of leverage (leverage is said to occur when reuse of one asset makes possible the reuse of a chain of other related assets further downstream in the process).

Reusability applies at different levels starting from the individual up to the ecosystem that individual is part of (Fig. 1). The ecosystem exceeds the community levels and comprises other

domains that impact upon the SG RDD, whereas reusability at individual level above all supports strengthening individual competences. Each of the layers needs to be considered in order to optimize the process of component and knowledge capture and transfer. To provide sustainable and practical solutions, the requirements specific to each layer need to be identified and analyzed.



Figure 1. Layers of knowledge reusability

The reusability of the different elements needed for the SG development and deployment process in the different layers depends, to a large extent, on the structure of and access to the information, the intellectual property rights, patents, as well as the documentation. At the individual level where the tacit knowledge becomes explicit, the capability to reuse is, in addition to the mentioned general limitation, depending on the individual knowledge and competence and thus often restricted to a single domain. Typical tools for accessing the necessary information are by using repositories and also knowledge management systems. The usability depends on how much information is available and if this information is structured in a suitable way. To provide this, a considerable amount of work has been carried out in recent years showing this potential [17-20]. The use of repositories in combination with knowledge management systems of existing games or games components helps indeed to increase the reusability and, at an individual and organizational level, also to support incremental innovation. However, disruptive innovation is lesser supported by this process. Using existing knowledge and information (here from a repository) as input to the design-process based on the principle of co-creative design [21], will to a higher degree utilize the creativity potential and thus better support the development of new products based on disruptive ideation. The use of a living lab (LL) approach, in which different stakeholder groups jointly develop ideas, before taking it further throughout the complete development process, is a concept that foster collaborative innovation and can thus be applied [22]. However, the use of LL concepts (a LL can be a part of or be an ecosystem) requires that the IPR of both the input and also the output (not only the game or learning materials, but also concepts, tools for development etc) have been properly checked in advance.

In addition, looking at the development process of SGs it can be seen that small teams often develop a specific solution on a given learning objective with no standard given for how to define the games in such a way that they are comparable. SG compliance to the SCORM model (Advanced Distributed Learning Initiative, 2005) [23] would help any teacher searching for a suitable game and lead to less double development, consequently bettering quality at lower cost. So far there are approaches for structured description, but none has reached the same widespread use of SCORM. An early approach on such taxonomy, called game genome, was presented in [17]. This taxonomy was specifically developed in order to identify reusable gaming elements within logistics. The objective is to support the implementation of the Intelligent Cargo Concept by deploying serious games elements in the vocational training based on existing games [18]. The taxonomy was applied for identifying reusable components in three dimensions [18] that would lead to a reduction of the development time. Main challenges were, however, related to the acquisition of the data that was used to fill the genome. The search algorithm heavily relies on the entered data to compare the games. When these values are

incorrect or incomplete, the results may be faulty. A further step towards a holistic framework was developed in the GaLA project. This framework forms the basis of a knowledge management system that gives access [24] to games described in a structured and holistic way. The tools described in the section can be used for all layers, whereas the living lab approach makes most sense when it is applied in an ecosystem context. The next section describes a tool that combines the framework [24] with the idea of the game genome [17].

2.2 Serious Games Reusability Point of Reference (SGREF)

The Serious Games Reusability Point of Reference (SGREF) has been designed as a tool that facilitates reusability within an SG ecosystem by the Technical Committee (TC) 2.5 Interoperability and Semantics operating within the Game and Learning Alliance network of Excellence (GALA-NoE) and has been strengthened through collaboration with other technical committees (TC2.1 Serious Games Mechanics; TC2.6 Assessment) and work packages in GALA (WP 04 -Industry and Stakeholder Engagement; WP 05 – Education; WP 08 - Support and Services) and with experts in the virtual reality community.

This research is based on the premises that source code modules are not the only kind of reusable SG assets. SG assets may include things as requirements, project plans, estimates, architectures, designs, user interfaces, game mechanics, game design patterns, test plans, test cases, data, quality plans, documentation, etc.

Managing a set of reusable SG assets requires that we know what items we have, where to find them and whether they are worth keeping. To achieve systematic reuse it is often essential to have an effective catalogue that connects to repositories.

Researchers have envisioned the SGREF as a tool that will enable online SG assets and knowledge collection and retrieval. This approach contributes to the successful development and deployment of SGs and enhances the decision-making capabilities of SG project teams that might not always be able to reunite all the necessary roles and expertise required for the development of an SG. Information will be collected mainly from SG or SG-related projects developed at national, European, and international level, but also from other online sources (Fig. 2).



Figure 2. SGREF: Serious Games Reusability Reference Point

This initiative considers the fact that a significant number of resources are not open source, and building repositories is not always a valid solution. Still, correct resource identification is a crucial step to fundamental reuse.

2.2.1 Main Sections

While access to references within SGREF is free, to add resources users need to authenticate by creating a free account or by using social login. Authentication is required in order to fundamnet the quality and the validation of the references, as these play a crucial role in sustainable reuse. Users will be ranked by their expertise and by their prestige within the community.

The following meta-descriptors have been proposed for the preliminary testing of the SGREF:

a. Title: The “Title” field is mandatory and can be rated by the users to reflect its relevance to the field. This will enable the validation of the SG assets contained by SGREF.

b. Tags: Tags are mandatory and will be suggested to the users based on the keywords introduced in the “Title” field. Users will be able to define their own tags. Users will be able to rate the tags defined by other users.

c. Short Description: In the “Description” field users can provide further information on the resource they refer. The “description” field is optional.

d. URL(s): Users need to provide at least one link to the SG assets they refer. Additional fields can be added.

e. Upload: Users can upload SG assets.

f. Recommended for: Users need to mention the category/ categories of user the SG asset is most relevant for: Researchers; Developers; Business; Teachers.

g. Satellite resources: Additional resources are automatically displayed by the application based on the hierarchical tag-based classification.

h. Comments: Users that post a reference to an SG asset can activate or deactivate comments.

Users are given the opportunity to ask questions, to rate references, to follow any new activity related to a reference, to share references and updates, to report broken links, request a reference, search for references based on advanced tools, etc.

Table 1. The Unity-SCORM Integration Toolkit Version 1.0 Beta

| | |
|---------------------|---|
| Title | The Unity-SCORM Integration Toolkit Version 1.0 Beta |
| Tags | SCORM, SCORM 2004 3rd Edition, SCORM 2004 4th Edition, SCORM Version 1.2, Unity, download, quick start guide |
| Short Description | The Unity-SCORM Integration Toolkit allows Unity developers to use simple methods, provided by a “ScormManager” object, to set the SCORM Run-Time Data Model elements without having prior experience with SCORM. |
| URL(s) | http://www.adlnet.gov/scorm-unity-integration/ |
| Upload | SCORM-Integration-.unity-package.zip |
| Recommended for | Developers, Researchers |
| Satellite resources | http://www.adlnet.gov/unity-scorm-quick-start-guide/ |
| Comments | |

Table 2. Standards for content sequencing

| | |
|---------------------|--|
| Title | Standards for content sequencing |
| Tags | Standards, IMS-SS, IMS-LD |
| Short Description | Using e-learning standards in educational video games. Authors: Ángel del Blanco, Eugenio J. Marchiori, Javier Torrente, Iván Martínez-Ortiz, Baltasar Fernández-Manjón Computer Standards & Interfaces 36 (2013) 178–187, Elsevier |
| URL(s) | http://www.e-ucm.es/drafts/e-UCM_draft_224.pdf |
| Upload | |
| Recommended for | Developers, Researchers |
| Satellite resources | |
| Comments | The main difference between IMS-SS and IMS-LD is that IMS-SS considers only scenarios where students are isolated, |

| | |
|--|---|
| | while IMS-LD supports collaborative activities. |
|--|---|

Users are those that create tags, and sometimes add resources. Users tag resources in order to find them later. They do not consider tagging particularly enjoyable. Moreover, users have a variety of different interests, needs, goals, and motivations. To maintain consistency, users will be provided with tag suggestions, based on the title of the resource that they intend to add. Users will be able to rate the tags introduced by other users, in order to fundament their validation by the community members.

Special attention is given to user motivation. SGREF will include gamification mechanisms that will stimulate participation based on a consolidated reward system, e.g. prestige, ratings, etc.

III. CONCLUSIONS

Reuse is an interdisciplinary phenomenon that builds on the business considerations one finds in enterprise modelling, the economic analyses of investment, the social analyses of process, and the psychological models of conceptualization, as well as the technical model of design and technology.

Considering the multi-facet issue of SG reusability, it has become necessary to establish what exactly are we trying to reuse, and where does the most payoff lie in reuse. The most difficult aspects of reuse are to know how to make something reusable and to know how to match a reuse opportunity to a foreseen solution hidden in a repository somewhere. Even if we are not all reuse engineers, we all have struggled with coaxing a supposedly reusable component into our work.

This paper presents core reusability challenges that communities face, advance ways to address them and tools that can support the development of reusability driven ecosystems. The SG community has to be prepared not only to assimilate emerging trends, but to support their efficient development and implementation. A Serious Games reusability Reference Point (SGREF) is presented as a prototype of an online tools that aims to provide a broad snapshot of the present state of the SG community by collecting references to SG assets that are reusable, standardized, and interoperable. This approach provides valuable insights for current and future initiatives in the field of SGs.

The vision and concepts of SGREF is to encourage SG developers and implementers, as well as researchers to consider adopting reuse. Once the SG community has developed a reusability-oriented mentality, it is necessary to facilitate access to reusable SG assets that support adoption in current practices. But which is the reusability potential of the SG community? How can the outcomes of the SG community be exploited optimally? What are the reusability opportunities between the SG community and other communities? Is cross-domain exchange enabled and prolific? These are questions to be addressed by further research.

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