Applying Gamification Principles to a Container Loading System in a Warehouse Environment

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Abstract—Gamification is a recent phenomenon that emphasizes the process of incorporating game elements, for a specific purpose, into an existing system in order to maximise a user’s experience and increase engagement with the system. In this paper, we discuss the effects of the introduction of the principles of gamification to a system for solving real-world container loading problems in a warehouse environment. We show how user engagement and confidence increases over time during interaction with the ‘gamified’ system, and we propose subsequent work for the thorough application of gamification to the system that completely abstracts the complicated container loading algorithms running in the background.

Keywords - gamification; container loading

I. INTRODUCTION

Gamification is a phenomenon that has in the last few years garnered a lot of attention with numerous applications particularly focusing on productivity and health fitness. It is defined as the use of game design elements in non-game contexts [1] and is mostly introduced into a system to increase user experience and user engagement [2], or to act as the means of actual user engagement where there is none. The increase in experience and engagement is considered to be the result of the effects obtained when leveraging people’s natural desire for learning and accomplishment.

In this paper, we discuss the application of the principles of gamification to a container loading system used to assist warehouse operatives during real-world container loading in a warehouse environment. We discuss the effects this has on the adoption of the container loading system, and show a systematic build-up of trust and familiarity over time of the system by the operatives. We then propose a fully gamified system as an abstraction that provides an interactive environment for the engagement of warehouse operatives with what would be otherwise complicated algorithms that solve container loading problems in the warehouse environment.

II. BACKGROUND

Information technology systems have long since been introduced into the workplace to bring about an increase in business performance [3,4]. Studies show however that such introduction does not always guarantee a positive result; the technology might either be very slowly adopted if adopted at all, or be overly complicated an ineffective at addressing the problem for which it was introduced [5,6]. Recent trends show the increased introduction of elements from game design into business computing systems in order to increase user engagement and improve or guarantee the adoption of the system in question (e.g. [7]). This phenomenon, of introducing gaming elements in a non-gaming context in order to increase engagement, is generally referred to as gamification [2]. This introduction of a computerised system as a means of increasing business performance and the further application of gamification elements in order to increase or retain user engagement, can be illustrated by our case study of a real-world problem in a UK distribution centre (henceforth known simply as the UKDC) of one of the largest bearing suppliers in the world.

The problem the UKDC faces is that of optimally selecting and loading groups of palletised goods onto containers such that the utility of the containers is maximised. The palletised goods, typically spread across different locations in a warehouse, are heavy and require the use of fork-lift trucks to move, stack and load them. The goods are made up of bearings packed into boxes, which are then packed into cartons that are arranged on any of several different pallet types; they are then shrink-wrapped and treated as an individual unit. Several practical constraints must be satisfied in order to produce a feasible solution to the problem.

To solve this important problem optimally, the UKDC have invested in research towards a computerised loading optimisation system in a bid to:

• increase overall loading performance,
• reduce the overall cost of hiring containers by optimally maximising the capacity of every loaded container thus reducing the overall number of containers used for loading,
• reduce the possibility of damage to goods that might occur because of non-optimal packing in the container, therefore reducing costs that might arise from replacing damaged goods, or as a result of customer fines for the receipt of damaged,
• provide greater customer satisfaction by speedily processing and loading customer orders for safe and prompt delivery, and to
• increase warehouse throughput: the more goods that are loaded and sent out from the warehouse, the
more room there is for new customer orders, which implies more business for the company.

This should have the overall effect of significantly improving their business performance and raising their competitive edge while providing greater customer satisfaction.

As part of the research collaboration with the UKDC, we have devised a load optimisation system to solve this problem. The system provides feasible solutions to the problem that are already proving very useful in practice. We refer the reader to [8] for further discussion of the problem and for the techniques we employed in devising the load optimisation system. A discussion of additional work done, that refines and extends the solutions obtained from the load optimisation system devised in [8], to provide aesthetically pleasing container layouts: an element that plays an important role in our gamification process, can be found in [9]. The initial attitude to the load optimisation system was very negative. We encountered resistance to the idea of a system that could ‘perform optimised loading operations’, as it could be interpreted as a system that could replace the warehouse operatives who currently performed such loading operations. It did not help that the output of the initial system prototype was plain text data (see Fig. 1) with numbers tersely showing item dimensions, weight, group membership, co-ordinate point locations, etc., that was difficult to interpret by the operatives. It also did not help that almost all the solutions produced from initial test runs consistently obtained 100% container utility (compared to the average of 85% utility from manual loading). Results like these only helped fuel uneasy feelings towards the system. What these tests did not show at the time was the flexibility that could be obtained from the solutions offered and how these solutions would greatly complement a loader’s experience; it was only later, after the addition of gamification principles to the system, that these factors came to light.

III. GAMEIFICATION APPROACH AND EXPERIMENTS

Based on the observed initial attitude towards the loading system, we realised early the need for a way to initiate and maintain user engagement with the system in order to increase its adoption. If the system adoption remained low, the system would be unable to make any impact that could cause any measurable effect on user performance.

Our main goal was therefore to ensure and increase user engagement in the loading system. We identified from literature that the application of gamification principles was a good fit for this goal, and we set about achieving the goal by identifying areas in the underlying system that could benefit from such principles. Table II shows the gamification sub-goals we set and the strategies we identified for tackling them. In the rest of this section, we discuss our implementation of some of these strategies and mention some of the observations resulting from the exposure of the resulting gamified system to the warehouse operatives. The rest of our observed results are discussed in the following section.

A. Defining conventions for visual layout representation

Our first steps involved building a visual representation for the text data output of the loading system (Strategy 1). We also set up naming and colour-coding conventions to identify the different types of pallets available for loading. The names used are based on names the warehouse operatives are already familiar with, and the colours used are easily identifiable primary colours. The visual representation is provided as a container layout that shows the exact placement of colour-coded palletised goods within a container (see Fig. 2). In subsequent interaction with the loading system, all loading operation results were presented using this visual representation. Our observations of these interactions revealed that our conceived visual representation, while a step in the right direction, came across as rigid and final to the operatives. This observation informed the need for a more flexible interactive interface, and became the basis for the identification and implementation of Strategy 2 and Strategy 7.

B. Providing an interactive simulation interface

In other to provide an interface that would be fun and interesting (Strategy 2), we decided to build a simulation interface that would incorporate the same visual representation conventions we had previously defined (see Fig. 3a). We made this interface accessible on a tablet because of how ubiquitous they have recently become; the idea being that the warehouse operatives would find it very familiar and easy to operate. We then presented the simulation interface in a manner that vaguely resembles the game “Tetris”. All together, this put a familiar interface in front of the complicated algorithms running behind the scenes in the loading system. As part of the interface design, and in keeping with our defined conventions, the interactive blocks used to represent palletised goods in the simulation were sized to scale and colour-coded appropriately. The end result of all this was an interactive interface that allowed for the easy modification of loading layouts in a simulated container (Strategy 7). We observed in subsequent user interaction a natural extension to the use of this interface that was not part of its intended design: i.e. the use of the simulation interface to check if loading plans (produced manually by the user; not generated by the loading system)
TABLE I.  DEFINED CONVENTION FOR LAYOUT REPRESENTATION

<table>
<thead>
<tr>
<th>Pallet name</th>
<th>Pallet dimension ratio</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-TYPE</td>
<td>12 x 8</td>
<td>Yellow</td>
</tr>
<tr>
<td>S-TYPE</td>
<td>8 x 7</td>
<td>Blue</td>
</tr>
<tr>
<td>N-TYPE</td>
<td>10.5 x 8</td>
<td>Red</td>
</tr>
<tr>
<td>E2-TYPE</td>
<td>8 x 6</td>
<td>Green</td>
</tr>
</tbody>
</table>

were feasible and could fit completely in the simulated container. This helped loaders check and reinforce their own loading knowledge. As part of our continuous evaluation of the system, this observed interaction helped further inform the gamification goals and became the basis for the identification and implementation of Strategy 8.

IV. RESULTS AND DISCUSSION

Our continuous observation of user interaction with the loading system throughout the entire gamification process was very informative. In fact, our observations of certain parts of the process directly informed further actions applied to other parts of the process.

As the conventions we introduced for the visual representation of the loading system’s output were easy to understand and relate to, they were easily adopted by the operatives and internalised; this brought about an increased engagement in the loading system. This adoption provided a common vocabulary for the loaders to use to represent loading terms and made it easier for them to understand and relate to the output of the loading system. It also brought about easier communication between us, the designers of the system and the loaders. Loading problems became easier to discuss as there were no longer any barriers to the understanding or the description of the problem in question: both parties to the conversation know what every term means and what each colour-coded figure represents. Our visual representation convention has now been internalised so much that it is used in the day-to-day discussion of general loading activities, not necessarily related to the loading system, in the warehouse (see Fig. 3b).

In our initial gamified representation of the loading system output, users were presented with loading layouts as seen in Fig. 2. The users often commented on how the system output was feasible but not how they would have loaded it themselves. This sentiment was expressed several times by different loaders. We observed that in the majority of the times this comment was made, the changes the users would have made to the generated layout were minor, and if these minor changes could be made, the user’s satisfaction would increase. Using this feedback, we further gamified the system to produce an interactive simulation interface. Using the interactive interface, loading plans were no longer set in stone, and loaders were free to modify the results of loading operations to better suit their preferred loading style (while still ensuring that the resulting new layout is feasible). This feature alone caused a significant increase in user engagement with the system.
As a result of this increased engagement, additional use cases of the gamified system were organically identified to include some functionality that was not an intended part of the original system design.

A. Use Case: Loading Feasibility Checker

The system can be used to check if a load can fit completely into the simulated container. As the simulation is built to scale, if the load fits in the simulation, it will most likely fit in the real world. The users used this functionality often to check the feasibility of planned loads in the simulation before proceeding with actual physical loading in the real world. This helped to catch any potential issues that could occur before actual physical loading is performed and to save time that would otherwise have been spent trying to rectify the issue, and also to save cost that could have been incurred as a result of any possible damage (we remind the reader that the real-world loading operations involve using fork-lift trucks to move around heavy goods; it is easier, faster and safer to plan out such activities first in the simulation and then loading, rather than directly proceeding with physical loading and trying to rectify any issues that develop as they manifest). This particular complementary behaviour of the system has proven to be very useful.

B. Use Case: Knowledge discovery tool

The system has sometimes generated and presented loading layout patterns that the loaders have never experienced or implemented before. A common comment we get from the users regarding this behaviour is “I never would have thought to do it that way”. Some of these interesting loading layouts allow the loaders to pack more goods onto the container than they previously thought possible; others introduce entirely new ways of packing loads efficiently. The loaders have adopted these new patterns and started to apply them to their own practical loading activities in the real world (see Fig. 5 and Fig. 6).

C. Use Case: Training aid

The system can be used as a training aid for teaching new or inexperienced loaders about loading and how to perform loading activities. We observed that this category of users found it easier to follow explanations of loading activities that were communicated to them visually. Learning is made easier if the user can see, instead of imagine, what exactly a load should look like, and what steps to take to complete a loading activity. The simulation interface provides such a visual communication interface that can help make loading activities more tangible. It also provides immediate feedback, such as finding out straightaway the answer to a question like: ‘what happens if I do this instead’, that can be invaluable to a learner.

In the long run, we observed that continuous interaction with the gamified system: checking the feasibility of loading plans, explaining loading concepts, experimenting with alternative plans for the same load, etc., gradually brought about trust in the system. The users had over time come to rely on the output of the system and on its capability to help check the feasibility of their own work. The system was now seen in a different light: i.e. an assistive technology brought in to complement their own effort and to help them perform their job more effectively. We acknowledge that making the system easily accessible and interactive played a big role in getting to this point; creating the simulation interface to presented the cryptic output of our complicated algorithms as easily accessible interactive layouts really helped increase the adoption of the system.

Overall, the application of gamification principles and the manner of our approach has had a very positive effect on the use of the underlying loading system to which we applied the principles. The gamified system has increased (and continues to retain) user engagement and has provided a fun and engaging environment for performing serious loading tasks and activities.
V. RELATED WORK

As gamification research is still in its infancy, several varied definitions exist for it in literature: Deterding, Nacke, Dixon and Khaled in [1] define it as “the use of game design elements in non-game contexts”; Zichermann and Cunningham in [10] define it as “the use of game thinking and game mechanics to engage users and solve problems”; Huotari and Hamari in [11] define it as “a process of enhancing a service with affordances for gameful experiences in order to support user’s overall value creation”; and Werbach and Hunter in [12] define it as “[the] use of game elements and game-design techniques in non-game contexts”. While the existing definitions might be inconsistent, a standard is emerging that emphasizes the use of “game elements” in “non-gaming contexts”. To this end, we identify with the definition of gamification as a process of incorporating game elements, for a specific purpose, into a system in order to maximise a user’s experience and increase engagement with the system. The important point in this definition is the presence of a purpose; the game elements incorporated into a system must have a specific purpose if an improvement in user engagement and motivation is expected [7].

A highly cited example of the successful application of gamification is Foursquare - a location based service that allows its users to check in at various locations using mobile devices. They used badges as a game element to leverage the desire of people to be connected, and saw an increase in the user engagement of their service. Li, Grossman and Fitzmaurice in [13] gamified a tutorial system to help new users learn AutoCAD. They employed gamification elements such as scoring - to provide feedback on performance, game levels - to provide a means of progression, missions - to provide a challenge, and rewards - to motivate users; and recorded an increase in engagement, enjoyment and performance among their users. McDaniel, Lindgren, and Friskics in [14] introduced gamification, through the use of badges as a sign of achievement, into a learning management system to motivate students towards certain behaviours desired by teaching staff. They observed that feelings of connectedness and competition drove students to engage with the system and reported an increase in engagement. de-Marcos, Garcia-Lopez, and Garcia-Cabot in [15] studied the effects of gamification on learning performance in an undergraduate course. Their results suggest a significant positive impact of gamification on learning performance.

In this paper, we showed our attempts at the incremental introduction of game elements - each to satisfy a pre-determined goal - to a decision support system for the sole purpose of increasing user engagement and changing the user’s perspective towards the system. Indeed, we can say that this process of introducing game elements into systems to improve engagement and change behaviour is a common theme across all applications of gamification, as it is an integral part of the definition of what gamification is. Whether or not an increase in performance or engagement is achieved is another matter, but the main design goal of the application of gamification must be to cause such an increase.

VI. CONCLUSIONS AND FURTHER WORK

The majority of the studies on gamification tend to generally indicate a positive effect on the system that is gamified; this is however highly dependent on the context in which the gamification is applied, and on the users of the gamified system [16,17]. We have taken some gamification principles and applied them to the industrial context of a warehouse environment, with warehouse operatives as the users of the system. Our preliminary investigations revealed that the introduction of the gamification principles had a very positive effect on the adoption of the underlying container loading system to which the principles were applied. Prior to the introduction of gamification principles to the system, the adoption of the system was poor with warehouse operatives being wary of a system they saw as a potential replacement for themselves and the work they do. Gamifying the system helped change this perception over time by presenting the system in a less threatening manner as an environment where one could have fun while doing work. This gamified interface on top of the system helped bring down the walls that had previously been set up, and helped the loaders see the system clearly for what it really was – an assistive system to help complement them in their loading operations and thus increase their overall performance.

Our next steps will involve setting up a scoring system and implementing a high scores table into the interactive simulation. The reasoning behind this is to leverage people’s natural desire for competition. Our initial tests already reveal the existence of a friendly competitive spirit, with individual loaders often wanting to know how other loaders perform when laying out particular container loads. Building the scoring system and the high scores table should hopefully further increase user engagement in the system as the loaders try to best each others’ scores. As gamification is an ongoing process that should be constantly evolved over time to improve the nature of the interaction with users [18], much of this investigation will be about the continuous capture and analysis of data such as how easy it is to use the system, how effective the learning experience is, does an inexperienced loader learn faster using the gamified system than using the traditional means, how the performance of inexperienced loaders compare to that of experienced loaders in the gamified system, does the performance obtained in the gamified system reflect actual real-world performance, and can the gamified system help reveal who is a better loader in practice; that will help refine the process of user engagement and ensure that the users are actually learning, ultimately resulting in an increase in the performance of warehouse operatives in their day-to-day loading activities.
**ACKNOWLEDGMENT**

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**REFERENCES**


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**TABLE II.** **IDENTIFIED GAMIFICATION STRATEGIES AND GOALS FOR THE SYSTEM**

<table>
<thead>
<tr>
<th>Problem</th>
<th>Goal</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>System adoption is low and system output is dull, non-engaging and difficult to interpret</td>
<td>A. Engage users visually with an intuitive interface</td>
<td>1. Present an interface with intuitive loading representation that is easy for users to use and understand</td>
</tr>
<tr>
<td></td>
<td>B. Retain user engagement and make system fun</td>
<td>2. Ensure the interface is simple and can make loading tasks fun</td>
</tr>
<tr>
<td></td>
<td>C. Encourage user learning, improvement and knowledge sharing</td>
<td>3. Provide loading ‘challenges’ that can be rewarded with special badges or trophies</td>
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<tr>
<td></td>
<td></td>
<td>4. Implement a scoring system to leverage user competitiveness which make users want to do better than others at loading tasks</td>
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<td></td>
<td>5. Provide repeatable tasks, which can be used in conjunction with score feedback, to reinforce learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Record completed user tasks that other users can easily access and learn from</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7. Provide users with a way to interact with the results from the loading system in order to allow modifications that result in new solutions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8. Provide an interface that allows one to quickly and easily check if a particular load layout will fit in a container</td>
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