On the application of Game Mechanics in Information Retrieval

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ABSTRACT

The exponential growth of digital generated content in the form of audio, video and complex data structures calls for novel methods and tools able to cope with the limitation of automated analysis techniques.
Gamification, the process of using game design methodologies and game mechanics to enhance traditional applications, is a promising tool that can help to increase the active involvement of humans in the Information Retrieval processes.
This work contributes to the emerging research field of Gamification in Information Retrieval by providing an overview on: 1) the fundamental elements of a game; 2) the major game mechanics that have been applied in traditional games and gamication techniques; and 3) an overview of the possible adoption of such techniques in a typical IR scenario.
The goal is to lay a path for the adoption of these new tools in IR systems, focusing on their application to the traditional building blocks of the query and content analysis processes.

Categories and Subject Descriptors

H.3 [**World Wide Web**]: Human Computation

General Terms

Design

Keywords

Gamification, Games with a purpose, Human Computation

1. INTRODUCTION

Recent attempts by major search engine companies in making the search process an engaging activity may suggest that people are approaching information retrieval systems not only to fulfill their information needs but also as a mean of entertainment during their spare time. Meaningful examples are the puzzle game *A Google a Day*[1] in which players must answer a question by performing Google search in an intelligent way or *Wikirace*[2], a race in which participants have to use links to travel from one Wikipedia page to another in the fastest possible way or reaching the destination with the least number of links. Channeling this interest into meaningful and active contributions from the users may help solving issues related to IR system, grown due to new media content to process and the limitations of automated analysis techniques in handling them. This work aims at investigating possible uses of game design techniques in IR systems, and is structured as follows:
Section 2 describes the steps of a typical process for defining and searching a collection of multimedia content.
Section 3 introduces the fundamental elements of a game, the major game mechanics that have been applied in traditional games and gamification techniques that could be relevant for our scope.
Section 4 defines some of the major issues that could be encountered during the design and use of an IR system, providing possible solutions with the introduction of suitable mechanics, design ideas or pointers to existing games that are already addressing the problem.

2. THE INFORMATION RETRIEVAL PROCESS

Information retrieval (IR) is the science of finding relevant material that satisfies an information need from within a large collection. The architecture of an IR system depends on two main factors: the characteristics of the multimedia data to handle and the kind of operations to perform on such data. Such a system should support different kinds of media: text, images, sounds, videos and even more complex data structures, like 3D models or medical scans. To perform the retrieval operation, the system has to rely on a mix of structured and unstructured data (metadata, semi-structured data, including data whose structure may not match the structure defined in the data schema) and extract some features from multimedia objects. On the fly scanning of the content in a collection when the system is queried is an impractical and often impossible solution; for this reason in the early stages of IR history was understood that avoiding linear scanning required indexing of the documents to be retrieved in advance. Such necessity has split the definition of an IR system into two distinct phases: Indexing and Query Handling. Figure 2 shows a model of a typical process for defining and retrieving multimedia content from a collection,

[1] http://googleaday.com

[2] http://thewikigame.com/

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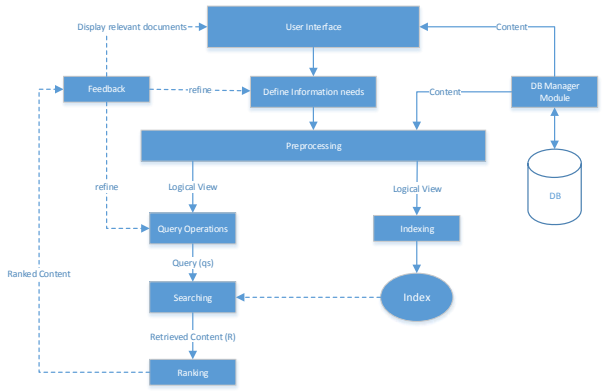

Figure 1: Reference architecture of an IR System

derived from the analysis of the models presented in [9][4] and comprising both these phases. The model identifies the steps involved in an IR process that could benefit from the introduction of gamification components to augment the capabilities of the system with human intervention.

Indexing is a setup phase necessary to speed up the search and retrieval of meaningful content, composed by the following steps:

- **Defining source and domain** The domain, containing the boundaries and nature of the retrieval task, is defined in order to identify and obtain a suitable collection to be processed. The collection could be an existing one or it may be created ad-hoc based on specific needs. Handling the collection, the operations to be performed on it, the content structure and which elements could be retrieved is an operation performed by a "database manager module"that interface itself with the collection to fulfill the desired tasks requirements.
- **Preprocessing** The content is handled differently, based on its nature, in order to generate logical views that could ease the indexing phase. For instance, preprocessing operations for textual content include lexical analysis, term resolution, stop word removal, stemming and analysis of tokens and the classification of documents; for image based retrieval system, this may include normalization of brightness and contrast, extraction of visual features such as color, textures, shapes or the segmentation of the image into regions.
- **Indexing** An index of the contents based on specific features is built on top of the logical view to allow fast searching over large collections.

The Query Handling phase is related to the interactive part of the system, when the user actually submits the query, and it is typically composed of:

- **Query Specification** The user's needs are specified through the user interface in different forms, depending on the content to be retrieved and the capabilities of the system. The query q_u could be expressed via Fuzzy predicates (find all images similar to a car), Content-based predicates (Find all objects containing an apple), Object attributes (Find all red images), Structural predicates (Find all multimedia containing a video clip).
- **Preprocessing** The query is parsed and compiled into an internal form depending on the content to be analyzed. The same operations have been previously applied to the contents that has been indexed by the IR system. This step yields to a refined query q'_u
- **Query Operations** Query operations further transform the preprocessed query into an optimized system level representation, q_s.
- **Searching** The query q_s is executed on top of a content source D to retrieve the set of relevant contents, R. Fast query processing is made possible by the index structure that was built previously.
- **Ranking** The set of retrieved content R is then ordered: documents are ranked according to the estimated relevance with respect to the user's needs.
- **Feedback** The results are returned to the user, which analyze the set of ranked documents based on her needs and redefine them or the whole query if unsatisfied.

3. GAME MECHANICS

3.1 Gamification vs Games with a Purpose

Even though Gamification, Serious Games and Games with a Purpose are terms that may seem interchangeably, the three concept are well defined and referring to different scopes:

- **Serious Games** are (digital) games used for purposes other than mere entertainment [14].
- **Games with a Purpose** (GWAP) are digital games that generate useful data as a by-product of play [16].
- **Gamification** relates to the use of game design techniques and game mechanics to enhance non-game contexts [5].

From these definitions, it is clear that Serious Games are a superset of the other two, specialized forms; the distinction between gamified applications and GWAPs instead lies in the motivation for their development.
Application gamification normally serves the purpose of increasing the performance of users of a platform with respect to given business objectives.
Conversely, GWAPs address a particular computational task with an ad hoc application exploiting human intervention.
Even though they have different uses, both of the two subsets share similar features that are found commonly in the Game Design field, while retaining specific mechanisms that are related to one subset or another.

Defining a list of possible mechanics that have been used in literature could thus hint a designer on the available choices that she could exploit; for this reason based on the best practices described in [10][7][6], it is possible to define first a list of "Game Elements"that characterize a game and then possible sets of game mechanics specific for each sub-genre.

3.2 Game Elements

These elements can be combined together to produce a variety of experiences that form the structure of what can be recognized as a game.

- **Rules** They define the admissible actions and the components of the game with which a player can interact.
- **Conflicts** Conflicts are a set of actions that have to be performed to reach a particular goal in the application but require efforts to be solved.
- **Rewards** Rewards represent the benefits obtained for having performed an action or solved a particular conflict.
- **Winning Conditions** Winning Conditions are the objectives that can be reached by overcoming particular conflicts.
- **Player Interactions** They regard the structure of interaction between a player, the system and any other possible player in the game, if present. The most common forms are cooperative, competitive or single player games.
- **Resources** They are assets owned by a player and used to accomplish a particular goal or collected to boast her prestige.
- **Feedback** It is used to inform the player about how well he is performing in the platform.

3.3 Games with a Purpose

Games with a Purpose are designed to turn a dull and boring task into an enjoyable experience worth in itself, triggering intrinsic motivation in the players.
Operations such as image, audio and video search are problems that, in order to be solved, require more than traditional machine learning approaches and at which humans, given their perceptual and abstraction capabilities, have far superior capacities. To elicit truthful responses, a designer could apply one of the typical agreement strategies (input-agreement, output-agreement, inversion problem)[16], rely on redundancy of the task to be performed, comparing the results with gold standards to judge the quality of a player or a mixture of these approaches. Unfortunately these guidelines are just detailing strategies to handle the results of players' contributions but are lacking the definition of suitable conflicts, elements that contribute deeply in the creation of a game. To our knowledge, no other work has tried to list a set of meaningful conflicts that could be applied in IR under the form of games with a purpose. Based on [3], [1], which provide an extensive literature on the matter, some of the most common gameplay mechanics, that may influence further idea and experimentation in the IR field, are provided:

- **Capture** to take or destroy opponents' resources, while avoiding the same occurrence on herself.
- **Chase** to catch an opponent or elude one, if you are the player being chased.
- **Rescue/Escape** to get a defined resource to safety.
- **Race** being the first to achieve a specific result.
- **Pattern Building** requires players to place resources in specific patterns, based on adjacent resources or resources in the same group/cluster, taking into consideration non-spatial properties like color, set completion, cluster size, occurrence in time, etc.
- **Memory** requires players to recall previous game events or information in order to reach an objective.
- **Action programming** every player must secretly choose the next 'n' turns, and then each player plays their turns out according to the choices made.
- **Guessing/Betting** encourage or require players to predict certain outcomes within the game, eventually by betting money (real or in-game).
- **Consensus** requires the players to agree on a certain topic or outcome.
- **Drawing** requires sketching objects, marking areas or drawing lines in one way or another.

3.4 Gamification

If Games with a Purpose are designed to solve a particular task, Gamification techniques mostly aim at providing extrinsic motivators to the players. Gamification techniques guide the users of a system towards expected behaviors defined by the designer, providing feedback and rewards on the outcome of their actions. Users often interact with a game or a system with no idea of its goals or fundamental drives; gamification is a mean to solve this onboarding problem. By comparing their abilities and contributions in the system with the other players, the users perceive a sense of fame that could work as an incentive to perform better and act more. The most meaningful gamification mechanics, based on the analysis of [18] [19], are the following:

- **Points** numerical values that represents a measure of the skill of a player or expendable resources at her disposal.
- **Leaderboards** ordered list of players based on the points they have obtained in a specific game or system.
- **Achievements & Badges** set of designer defined tasks used to guide the users towards a certain goal and track their progress in a system.
- **Collection & Virtual Goods** game assets with perceived or real monetary value.
- **Unlockable Features** Benefits or special characteristics of the system that can be accessed just by the most valuable players.
- **Status & Fame** Obtaining social endorsement based on the results obtained within the system.
- **Customization** possibility to modify the interface or hidden settings within a system to tailor it against one's own needs.

4. MECHANICS TO IR MATCHING

Given the IR model that has been described in Section 2 and the components detailed in Section 3, it is possible to identify some of the major problems related to IR systems and how the introduction of mechanics for the creation of Games with a Purpose could aim in the design of interactive systems exploiting human contributions.
The matching of the phases with suitable mechanics is summarized in Table 1

4.1 Gamified Indexing

- *Content Acquisition* producing a collection of content related to an identified domain is a task that is well suited for human contribution: if for text search engines the content is retrieved from closed collections or from the Web, multimedia content can be acquired by multiple heterogeneous means or even requested as user's contribution.
  Exploiting the Collection mechanics, the retrieval of meaningful content could be related to acquiring a collection of items in a game. This is the case for Google's GWAP Ingress[3], in which the players contribute in creating a collection of points of interest in Google Maps by taking pho-

[3]www.ingress.com

Table 1: Game Mechanics Matching Summary

IR Phase	Conflicts	Gamification
Content Acquisition	Guessing/Betting, Race, Capture	Collection, Virtual Goods
Preprocessing	Drawing, Pattern Building, Consensus	Points, Leaderboards, Achievements
Indexing	N/A	N/A
Query Specification	Consensus, Pattern Building, Guessing/Betting, Race	Points, Leaderboards, Achievements
Query Operations	N/A	N/A
Searching	Race, Consensus, Guessing/Betting, Capture	Points, Leaderboards, Achievements
Ranking	Consensus	Points, Leaderboards, Virtual Goods
Feedback	Consensus, Memory	Points, Leaderboards, Achievements, Customization

tos of real world elements, virtually claiming them as their virtual property (Collection, Virtual Goods).
In a similar way, clustering could be used to create different topical content collections. Given a topic and a collection, players could "adopt"(collect) a particular content not previously claimed by someone else and related to the stated topic, receiving points in the process. The more time passes, the harder the discovery of unclaimed content would be, thus newly adopted items would assign more points to their new owners, exploiting a Racing mechanism that could lead to faster collections creation.

- *Preprocessing* Even though the preprocessing of textual content prior to indexing can be performed more efficiently by machines, given the speed at which they can process words in a standardized way for operations like stemming and tokenization at a scale, this does not always hold for multimedia content. The perceptive and cognitive skills of human beings can be exploited to perform operations like object recognition and semantic analysis to define suitable features for indexing. Most of the GWAP that have been created so far are used to solve multimedia problems at this level. For instance *ESP*[15] and *TagATune*[11] use Consensus to provide semantic tags to images and audio files to allow textual search of such content, while *Peekaboom*[17] *Sketchness*[8] exploits Drawing and Consensus for object recognition and image segmentation.
- *Indexing* Provided the features acquired with automatic algorithm or human contribution, this phase requires just to process them and build suitable index structures with the aim of maximizing retrieval efficiency. Given the nature of this task, human intervention seems unfeasible due to scale and possible inconsistency in the provided results.

4.2 Gamified Query Handling

- *Query Specification* The first step that involves directly the user of an IR system. The major issues are related to the understanding of the user's information needs and dealing with ambiguity that may derive from the formulation of the query. The real intent of the querying user could be inferred interactively by making him a player in a consensus game in which, given the query, the participants must agree on the most meaningful query result (Consensus). To augment the autocompletion features present in modern search engines, given a query and a set of results, a group of players could "bet"virtual currency in a Bingo like game on the items that would probably be chosen by the user that has submitted the query, thus hinting him on possible content similar to the one that he is searching; in the case in which a hinted item was picked, the suggesting player would gain back a certain amount of virtual currency (Betting). These approaches could be effective when the content to be identified is a multimedia one. In *PageHunt*[13], a single player game, a user is given a set of query results and the goal is to provide the most meaningful set of keyword that could lead to such results, thus inferring the domain related to the query (Pattern Building). A fundamental aspect in the design of a possible gaming experience in this step is the timing constraints dictated by the user's requirements and her will to wait, time that could be reduced by applying racing mechanisms, useful to elicit prompt responses (Race). A complementary approach could focus on improving not the search engine itself but the ability of the user to become a better searcher, by actively instructing him on how to effectively use the system, defining a progression path through gamification means, like a set of sequential achievements to unlock (Achievements).
- *Preprocessing* This step is similar to the one performed in the Indexing phase, thus the same considerations still hold, but issues related to the response time for the processing of the content are also introduced. While in the Indexing phase the preprocessing could have taken even long time periods, given the fact that it can be done offline, in this case the available time is tied to the requirements of the user that has submitted the query and the availability of players in the system. Racing mechanisms influencing the users to act promptly may slightly alleviate the problem.
- *Query Operations* This phase transforms the preprocessed query into a system representation that could be applied on the internal data structure of the IR system. Human intervention in this step is not necessary since these operations are purely machine-based.
- *Searching* This step is similar to the Content Acquisition step that has been performed in the Indexing phase, and thus the same principles applies, by narrowing the retrieval scope to an established collection and compare the retrieved content with respect to the specified query. Once more, time issues could be critical, thus implementing time constraints conflicts or racing mechanism is necessary. In *Search War*[12], for example, a pair of players are each given a unique search query with the aim of guessing their opponent's search query first to retrieve the perceived purpose behind a page and perform relevance judgment (Racing).

- *Ranking* Ranking the retrieved items may be an interesting case for exploiting human contribution through games. Even though the standard approach for ranking is usually performed by ranking items according to their relevance, especially topical relevance, a particular content may be preferred by a user based on several characteristic, including quality, authoritativeness, readability. For multimedia assets, the judgment may be based on aesthetics, artistic qualities or other factors. The relevance of the content is typically based on explicit relevance judgments for a set of training items, usually acquired from a small number of "experts"in a controlled setting; yet it may be difficult for anyone but the issuer to accurately judge the relevance of the results. Consensus mechanisms may reduce the influence of the issue. In *Picture This*[2], for instance, the data acquisition problem is solved through an agreement game in which two participants are shown a sequence of queries and corresponding sets of image results; they are both asked to choose the best image for each query, and every time they agree they are awarded credits redeemable with real world prizes (Consensus).
- *Feedback* The results retrieved by the system are presented to the user and, eventually, refined by performing the Query Specification and Query Operations steps once more. The most crucial aspects in this phase are 1) understanding if the query results are effectively matching the user's information needs and 2) timeliness in obtaining the relevance assessment. In a gamified IR system, it would be the user herself to mark as relevant the results to the system with the goal of obtaining points or achievement and improve similar researches in the future. Other problems may be related to information filtering, requiring for example the removal of duplicates in the list of retrieved results; in this case, the user may recall previously encountered content and mark duplicates to earn points based on the number of duplicates discovered with the same rewards as before, and removing such results for future issued queries.

5. CONCLUSIONS

A better understanding of game mechanics and gamification techniques is key for their successful adoption in information retrieval. In this paper, we present a guided overview on the state of the art in the field. Guided by the main building blocks of the indexing and query processes, we detail the main game and gamification mechanism that could be applied to foster the active engagement of humans in their execution.

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