STARS4ALL

Deliverable

D4.4

# Games Design

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| **Abstract (for dissemination)** | This deliverable reports about the introduction of gamification in the project LPI. After an introduction on the various methods and techniques, we illustrate the objectives of the game generic enablers that we are developing; moreover, we also summarize the current status and the plans for the introduction of gamification in two of the project LPIs. | | | | | | |
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# 1. Introduction

This report represents the first deliverable related to objective O4.1 “Implement Gamification”, and specifically to task T4.1 “Gamification Design & Mockups”. It includes the results of the first six months of the project in relation to designing gamified applications to support raising collective awareness about light pollution and engaging general audience in the STARS4ALL project’s themes.

Starting from the previous experience and achievements of the involved partners, this document delineates the global approach, the timeline and the early results of WP4 with regards to gamification. The current outcomes are both oriented to make gamification concrete within the initial project’s Light Pollution Initiatives (LPI) and to pave the way to external project contributors that could be interested in developing new LPIs by adopting a similar approach.

The deliverable is structured as follows. Chapter 2 introduces the main concepts related to the approaches known in literature and related to crowdsourcing and gamification; the chapter also presents a list of gamified applications that we developed in the past and on which basis we build the current work. Chapter 3 explains the types of data linking problems that we address in the project; this formalization is the basis for our game enablers, whose basic design choices and features are illustrated in this chapter; the final implementation as well as the respective detailed documentation will be carried out in the following months.

The envisioned game enablers are expected to be adopted in the projects LPIs. Hence, Chapter 4 introduces LPI7 “European Cities at Night” by summarizing the activities initiated before the start of the STARS4ALL project with the Cities at Night initiative and by describing its challenges and objectives; moreover the needs for gamification are exposed and the design of the gamified version of “Dark Skies ISS” is described in detail. Similarly, Chapter 5 introduces LPI4 “Detecting Inefficient Outside Lighting” by explaining the purpose and the previous experiences with this regard; then, some initial ideas and possible plans towards the gamification of this LPI are given.

Finally, Chapter 6 recaps the steps and activities that will follow in the next project period with the expected results.

# 2. State of the art and previous work

In STARS4ALL Work Package 4 "Citizen Sensing & Gamification", we address the problem to involve human users in collecting, validating and analysing data related to light pollution. Ideally, those tasks could be done automatically by means of intelligent systems with advanced algorithms. However, it is well known that some of these tasks, which are very complex for machines (e.g. interpreting the content of media like images), on the other hand are very easy for humans. Hence the idea of involving and engaging human "workers" in performing those tasks.

Currently, the existing processes used to exploit human contributions are crowdsourcing, Human Computation and Citizen Science. Moreover, to increase the engagement of the crowd (the number of users involved, the effort spent in performing the tasks, the duration of the involvement), gaming elements are also usually added to the ordinary job execution.

In the following sections we explain in detail what crowdsourcing, Human Computation and Citizen Science mean and in which way the gamification aspects can be added to these kind of processes. In the end, we present an overview of our previous experience in gamified applications.

## 2.1 Methods to involve users: Citizen Science, Crowdsourcing and Human Computation

In literature, there are several different approaches to involve users in the execution of tasks. While different in their original objectives, those disciplines share common features.

*Citizen Science* is the involvement of volunteers to collect or process data as part of a scientific or research experiment; those volunteers can be the scientists and researchers themselves, but more often the name of this discipline "implies a form of science developed and enacted by citizens" including those "outside of formal scientific institutions" [20], thus representing a form of public participation to science. Formally, Citizen Science has been defined as "the systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on a primarily avocational basis"[1].

*Crowdsourcing* [18] is the process to outsource tasks to a "crowd" of distributed people. The possibility to exploit the Internet as vehicle to recruit contributors and to assign tasks led to the rise of micro-work platforms like the very popular Amazon Mechanical Turk marketplace[2], thus often (but not always) implying a monetary reward. The term Crowdsourcing, although quite recent, is used to indicate a wide range of practices[11]; however, the most common meaning of crowdsourcing implies that the "crowd" of workers involved in the solution of tasks is different from the traditional or intended groups of task solvers. Therefore, in a sense, the Citizen Science approach defined above can be seen as a typical crowdsourcing approach, in that amateurs are involved to perform scientific tasks in place of professional researchers and scientists.

*Human Computation* [23] is a computer science technique in which a computational process is performed by outsourcing certain steps to humans. Unlike traditional computation, in which a human delegates a task to a computer, in Human Computation the computer asks a person or a large group of people to solve a problem; then it collects, interprets and integrates their solutions. The original concept of Human Computation by its inventor Luis von Ahn derived from the common sense observation that people are intrinsically very good at solving some kinds of tasks which are, on the other hand, very hard to address for a computer; this is the case of a number of targets of Artificial Intelligence (like image recognition or natural language understanding) for which research is still open.

[1] http://www.openscientist.org/2011/09/finalizing-definition-of-citizen.html
[2] http://www.mturk.com/

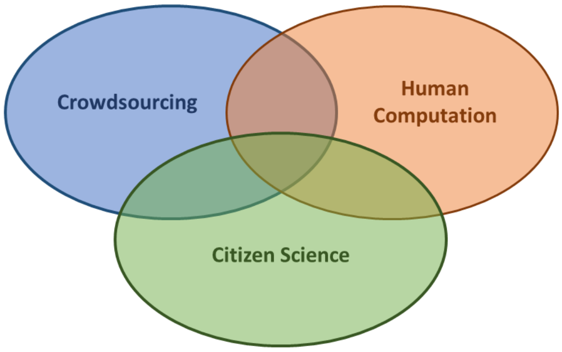


Figure 2.1: Overlapping between Citizen Science, Crowdsourcing and Human Computation.

Figure 2.1 graphically shows that the three introduced methods overlap. Indeed, even if those techniques originate from different scientific communities in order to address different problems, it is undoubtful that they share a number of characteristics: the involvement of a "crowd" of participants with little or no required skills, the objective to collect information through the help of people, the need to compare and aggregate information coming from different people with possibly diverse levels of reliability.

In the STARS4ALL project, we do not limit ourselves to a single approach, but we aim at choosing and tailoring our methods and tools so to achieve the goal of creating awareness about and potentially also fighting light pollution. While it is unlikely that we will employ paid crowdsourcing, we will for sure perform Citizen Science campaigns and will leverage, whenever suitable, Human Computation techniques.

## 2.2 Motivation and incentives: Games and Gamification

As mentioned above, in order to effectively engage users, different incentives can be adopted. In the case of crowdsourcing, workers are usually paid to execute the tasks. However, in other cases, alternative motivations can be leveraged: personal interests, public recognition, fun. In this section we present the existing models for using games as incentives, thus designing gamified applications.

There are three main models that can be adopted to turn a data collection/validation task into a gamified application.

*Gamification [16] applied to Citizen Science tasks.* The term "Gamification" is the process adding game-design elements and game principles in non-game contexts [8] to improve user experience and engagement, loyalty and fun. This method consists in introducing typical game elements within traditional processes of Citizen Science and crowdsourcing. The final user is perfectly aware that he/she is executing a task and the application rewards users with game-like incentives (e.g. points, badges, leaderboards).

*Game With a Purpose (GWAP)* [29]. A GWAP is a gaming application that outsources steps within a computational process to humans (Human Computation task) in an entertaining environment. The player is usually unaware of the hidden purpose and he becomes a player of the game, simply to meet game challenges. In this sense, the game is said to have a "collateral effect", i.e. players' actions are exploited to solve a hidden task. The user's contribution is fostered by the desire for success within the game. To be effective, a GWAP should be carefully designed to provide an effective mechanism to address the Human Computation task and to assure a continuous involvement and contribution of users/players.

*Serious Game* [9]. A Serious Game is a simulation of real-world events or processes, usually to train or educate users. The most popular example of this kind of applications is the flight simulator.

The final user is interested to learn to solve a task/problem (e.g. a pilot interested in learning to fly an airplane). The application, which is not necessarily a game, rewards users with knowledge and skills acquisition.

Sometimes, a game can also be designed as an hybrid composition of the above categories. In STARS4ALL, we will possibly introduce gamification in all our applications, so to exploit the fun incentive in citizen engagement. Depending on the specific goal and use case, we will either apply gamification to Citizen Science campaign or we will develop Games with a Purpose or we will adopt a hybrid and multi-purpose approach.

## 2.3 Previous experience in gamified applications

Our previous experience includes the development of different kinds of games using both the GWAP model and the gamification approach. Although we didn't develop any serious game in the past, we illustrated them in the previous section as well for the sake of completeness.

We designed and developed four GWAPs, from the simpler Indomilando[3] and Land Cover Validation game[4] to the more complex UrbanMatch[5] and Urbanopoly[6].

*Indomilando* [7] is a web-based Game With a Purpose aimed to rank a quite heterogeneous set of images, depicting the cultural heritage assets of Milan. The user has to choose the right picture related to an asset and, as an incentive, he gains points for each correct answer. This is the Human Computation mechanisms we adopted: the more a photo is correctly identified by players, the more recognizable it is (and thus the higher in the ranking). Furthermore the player can view the assets he played with on a map and display their historic and cultural description, as shown in Figure 2.2. This is a learning reward the player gains playing this game.


Figure 2.2: Indomilando: gameplay (left) and asset visualisation on a map (right).

*The Land Cover Validation* game [3] is designed according to a Human Computation methodology to engage Citizen Scientists in the validation of land cover data in the Como municipality area (in Lombardy, Italy). The user is requested to classify the areas in which two different land cover maps disagree (DUSAF[7] classification made by Lombardy Region and GlobeLand30[8] by the Chinese government). As a classification task, this process aims to create links between a set of images (aerial photos) and a set of given categories (land use types i.e. residential, agricultural areas...), as shown in Figure 2.3. As regards the entertaining environment, we can consider this application a GWAP even though the purpose of the game is not so hidden, as common in GWAPs.

[3]http://bit.ly/indomilando
[4]http://landcover.como.polimi.it/landcover/
[5]http://bit.ly/urbanmatch
[6]http://bit.ly/u-website
[7]http://www.geoportale.regione.lombardia.it/en/home
[8]http://www.globallandcover.com/GLC30Download/index.aspx

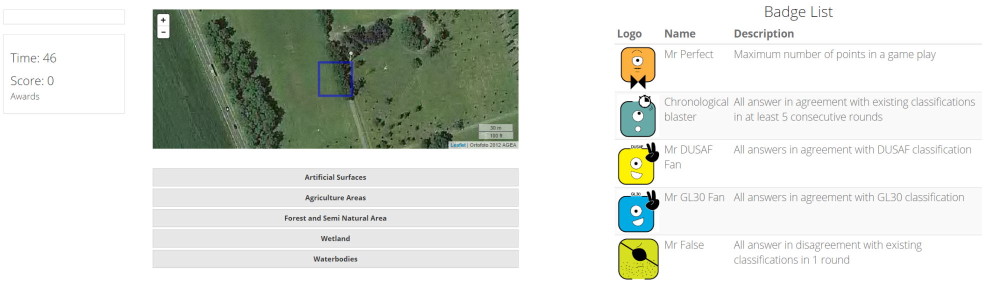


Figure 2.3: Land cover validation game: picture classification (left) and list of badges (right).

*UrbanMatch* [6, 5] is a location-based Game With a Purpose in the form of a mobile application, whose graphical interface is shown in Figure 2.4. Specifically, UrbanMatch is aimed at exploiting players' experience of the urban environment to correctly link points of interests in the city with their most representative photos retrieved from Web sources. The purpose of UrbanMatch is to derive meaningful links between a datasets containing the points of interest (POIs) in a urban environment and a dataset with the images depicting those POIs and retrieved from Web social media; among all photos taken in the proximity of a POI, UrbanMatch is designed for linking the most representative ones to that POI. The application is fully a game, in that players are faced with the challenge of pairing photos of the same point of interest, therefore, the actual purpose is completely hidden in the gameplay; the gaming incentive is constituted by the leaderboard of players scoring the highest number of points.


Figure 2.4: Urbanmatch game.

*Urbanopoly* [4] is a location-based GWAP that performs crowdsourcing tasks, as the collection of high-quality information about urban environments. This application exploits a Human Computation approach, because, while playing, users are requested to provide valuable information about the urban environment they are moving in. Inspired by the popular board game "Monopoly", the gameplay is aimed at trading venues and earning money, so to create a personal venues' portfolio and become the greatest landlord while moving in the player's own neighborhood (cf. Figure 2.5). Those venues are real places around the player selected from OpenStreetMap, such as shops, restaurants, and monuments. As "side effect", the game has the purpose to collect valuable and trustworthy information about the game venues.

Moving away from full games, we also have some experience in designing gamified applications.

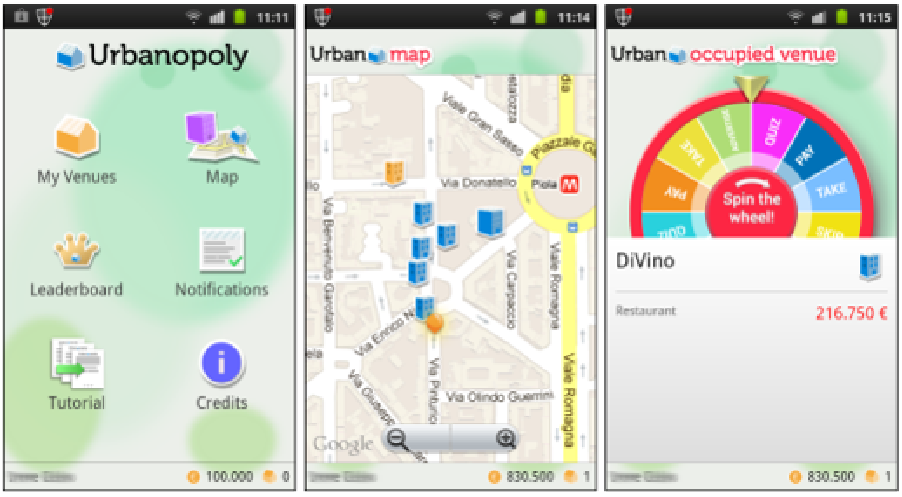


Figure 2.5: Urbanopoly game.

More specifically, we designed and developed a Citizen Science application, called *Pic-MI-App*[9], for collecting data and images about Milan's cultural heritage. Data is collected with the contribution of citizens, boosting their engagement through some typical gamification mechanisms: users uploading their best pictures of the cultural assets of Milan (see Figure2.6) obtain badges to recognize their contributor "status" (going from being a "tourist" that provides only a few pictures to becoming a "major"); moreover, the images are shown in a gallery, thus also leveraging the incentive of public recognition.


Figure 2.6: Pic-MI-App: selection of a cultural heritage asset (left) and picture upload (right).

[9] http://bit.ly/picmiapp

# 3. Towards Generic Game Enablers

All the games described in the previous chapter have to handle the problem of generating links between resources of different types. Some examples of resources in our games are pictures, urban points of interest (as in *UrbanMatch* and *Urbanopoly*) and land use categories (as in *Land cover validation game*). In this section, we first define the problem of data linking and its possible more specific use cases, then we explain how our game enablers are designed in order to address the data linking problem with a Human Computation/Citizen Science approach.

## 3.1 Data Linking: preliminaries

When formalizing the problem of data linking we make explicit reference to the Semantic Web [2] and RDF [24], in which a **link** is defined as a *triple* consisting of three parts: a subject, a predicate and an object:

- a *subject* is always a *resource* identified by a URI and it can be characterized by a type, i.e. the resource can be an instance of a class (e.g., STARS4ALL is a project);
- an *object* is either a *resource* (like a subject, thus identified by a URI) or a *literal*, i.e. an instance of a primitive type (e.g. a number, a string, etc.);
- a *predicate*, also referred to as property or sometimes also relation, is identified by a URI and can be characterized by a domain and a range (codomain) which respectively restrict the possible value that the predicate's subject and the predicate's object can assume.

It is worth noting that a resource that assumes the role of subject in a triple could also assume the role of object in another triple; the set of links can be represented by a directed graph in which subjects and objects represent vertexes and predicates represent the edges with the direction from the subject to the object.

Data linking is rooted in the record linkage problem studied in the databases community since the 1960s [13]; for this reason, in the Semantic Web community, the term is often used to name the problem of finding equivalent resources on the Web of linked data [14]; in this meaning, data linking is the process to create links that connect subject- and object-resources from two different datasets through a property that indicate a correspondence or an equivalence (e.g. `owl:sameAs`).

We prefer to define **data linking** as the general problem of creating links in the form of triples, without limitation to specific types of resources or predicates, nor necessarily referring to linking across two different datasets or knowledge bases (data linking can happen also within a single dataset or knowledge base). We give the following conceptual definitions.

**Resources**: *$\mathcal{R}$ is the set of all resources (and literals), whenever possible also described by the respective types. More specifically: $\mathcal{R} = \mathcal{R}_s \cup \mathcal{R}_o$, where $\mathcal{R}_s$ is the set of resources that can take the role of subject in a triple and $\mathcal{R}_o$ is the set of resources that can take the role of object in a triple; as said above the two sets are not necessarily disjoint, i.e. it can happen that $\mathcal{R}_s \cap \mathcal{R}_o \neq \varnothing$.*

**Predicates**: *$\mathcal{P}$ is the set of all predicates, whenever possible also described by the respective domain and range*

**Links**: *$\mathcal{L}$ is the set of all links; since links are triples created between resources and predicates it is: $\mathcal{L} \subset \mathcal{R}_s \times \mathcal{P} \times \mathcal{R}_o$; each link is defined as $l = (r_s, p, r_o) \in \mathcal{L}$ with $r_s \in \mathcal{R}_s, p \in \mathcal{P}, r_o \in \mathcal{R}_o$. $\mathcal{L}$*

*is usually smaller than the full Cartesian product of* $\mathcal{R}_s, \mathcal{P}, \mathcal{R}_o$*, because in each link* $(r_s, p, r_o)$ *it must be true that* $r_s \in domain(p)$ *and* $r_o \in range(p)$*.*

**Link scores**: $\sigma$ *is the score of a link, i.e. a value indicating a sort of confidence index on the truth value of the link; usually* $\sigma \in [0, 1]$*; each link* $l \in \mathcal{L}$ *can have an associated score.*

## 3.2 Different cases of Data Linking

Given the previous definitions, we then split the general data linking problem in a set of more specific cases as follows.

**Resource/Link collection**: *A resource* $r$ *is created and added to* $\mathcal{R}$*; this is usually triggered when a link is to be created, but at least a component of the triple is missing.*
In other words, given a triple pattern of the form $(r_s, p, \cdot)$, with $r_s \in \mathcal{R}_s, p \in \mathcal{P}$, first the resource $r_o$ is created and added to $\mathcal{R}_o$ and then the respective link $l = (r_s, p, r_o)$ is created and added to $\mathcal{L}$. Similarly, this case can be applied to triple patterns of the form $(\cdot, p, r_o)$ or even $(r_s, \cdot, r_o)$ to add a new predicate $p$ to $\mathcal{P}$.
For example, this is the case of image tagging: given a list of resources of type "picture" in $\mathcal{R}_s$ and the predicate `rdfs:label` $\in \mathcal{P}$, the task is to create meaningful tags (string literals) representing descriptive tags for the pictures, to add those tags to $\mathcal{R}_o$ and then to create the links $(image, label, tag)$.

**Link creation**: *A link* $l$ *is created: given* $\mathcal{R} = \mathcal{R}_s \cup \mathcal{R}_o$ *and* $\mathcal{P}$*, the link* $l = (r_s, p, r_o), r_s \in \mathcal{R}_s, p \in \mathcal{P}, r_o \in \mathcal{R}_o$ *is created and added to* $\mathcal{L}$*.*
The difference to the previous case lies in the fact that all three components of the link to be created exist, i.e. they are already included in the sets $\mathcal{R}$ and $\mathcal{P}$.
It is important to note that ***classification*** can be seen as a special case of link creation in which, given a resource $r_s \in \mathcal{R}_s$ to be classified and the predicate $p \in \mathcal{P}$ indicating the relation between the resource and a set of possible classes $\{class_1, class_2, \ldots, class_n\} \subset \mathcal{R}_o$, the resource $r_o \in \{class_1, class_2, \ldots, class_n\}$ is selected to create the link $l = (r_s, p, r_o)$.
For example, this is the case of music classification: given a list of resources of type "music tracks" in $\mathcal{R}_s$, the predicate `mo:genre` $\in \mathcal{P}$ and a set of musical styles in $\mathcal{R}_o$, the task is to assign the music style to each track by creating the link $(track, genre, style)$.

**Link ranking**: *Given the set of links* $\mathcal{L}$*, a score* $\sigma \in [0, 1]$ *is assigned to each link* $l$*. The score represents the probability of the link to be recognized as true. Links can be ordered on the basis of their score* $\sigma$*, thus obtaining a ranking.*
In other words, we consider a Bernoulli trial in which the experiment consists in evaluating the "recognizability" of a link and the outcome of the experiment is "success" when the link is recognized and "failure" when the link is not recognized. Under the hypothesis that the probability of success is the same every time the experiment is conducted, the score $\sigma$ of a link $l$ is the estimation for the binomial proportion in the Bernoulli trial.
In the case of Human Computation, crowdsourcing or Citizen Science, each trial consists of a human user that evaluates the link and states that, in his/her opinion, the link is true (success) or false (failure); the human evaluators, if suitably selected, can be considered a random sample of the population of all humans; therefore, aggregating the results of the evaluations in the sample, we can estimate the truth value of a link for the entire population, by computing the probability of each link to be recognized as true. Then, ordering links on the basis of their score means having a metrics to compare different links on their respective "recognizability".
For example, this could be the case of ranking photos depicting a specific person (e.g. an actor, a singer, a politician): given a set of images of the person, human users' evaluation could be employed to identify the pictures in which the person is more recognizable or more clearly depicted.

**Link validation**: *Given the set of links $\mathcal{L}$, a score $\sigma \in [0,1]$ is assigned to each link $l$. The score represents the actual truth value of the link. A threshold $t \in [0,1]$ is set so that all links with score $\sigma \geq t$ are considered true.*
The difference between link validation and the previous case of link ranking is twofold: first, in link validation each link is considered separately, while in link ranking the objective is to compare links; secondly, while in link ranking the human judgment is used to estimate the subjective opinion of the human population, in the case of link validation the hypothesis is that, if a link is recognized as true by the population of humans (or by a sample of that population), this is a good estimation of the actual truth value of the link. The latter is also the reason for the introduction of the threshold $t$: while the truth value is binary (0=false, 1=true), human validation is more fuzzy, with "blurry" boundaries; the optimal value for the threshold is very domain- and application-dependent and it is usually experimentally estimated.
An example of link validation would be assessing the correct music style identification in audio tracks: it is well-known that sometimes music genres overlap and identifying a music style could also be subjective (e.g. there is no strict definition of what is "rock"); employing humans in this validation would mean attributing the most shared evaluation of a music track's genre.

As mentioned before, in the last two cases, the human evaluation of a link can be considered a Bernoulli trial: each link $l$ is assessed $n$ times by $n$ different users $u$; the link is recognized as true $X$ times (with of course $X \leq n$); each user $u_i$ can be more or less reliable and, in some cases, it is possible to estimate his/her reliability $\rho_{u_i}$. Therefore, the score of a link is $\sigma = f(n, X, \rho_u)$, i.e. it is a function of the number of trials $n$, the number of successes $X$ and the reliability values of the involved users $\rho_u = \{\rho_{u_1}, \rho_{u_2}, \ldots, \rho_{u_n}\}$.

## 3.3 Game enablers for Data Linking

Starting from our previous experience in the Gamification and GWAP approaches, we can provide citizens interested in running a LPI with guidelines and software "building blocks" to build their own gamified application. The *generic game enablers* that the project will offer to those citizens are therefore constituted by those guidelines together with the templates for building gamification or GWAP applications.

We envision two types of enablers: (1) an enabler to build *pure Gamification* applications, i.e. Citizen Science systems enriched with gaming features, and (2) an enabler to build *GWAPs*, i.e. fully-fledged games with the "hidden" purpose of collecting or assessing information. Even if they share similar concepts, those two types of enablers serve slightly different objectives, therefore we think it valuable to provide two distinct enablers.

### 3.3.1 Examples of guidelines

In order to decide whether to develop one kind of application or the other, the guidelines come in handy. While they are not yet fully developed, we give here some hints on the types of questions a developer should ask to himself in order to decide if, what and how to employ our generic game enablers to build his desired application with a gaming flavour.

The first question would be: *what problem do I need to solve?* In other words, the first step will be the problem analysis. If it can be traced back to a data linking problem (as illustrated in the previous sections), then our enablers can be adopted, because they are exactly intended to address that kind of issues.

The second question would be: *what is the atomic task my application's users will be asked to execute?* The atomic task should not be too simple, because the user needs to be engaged, but it should not be too difficult either, because the user does not have to feel frustrated; according

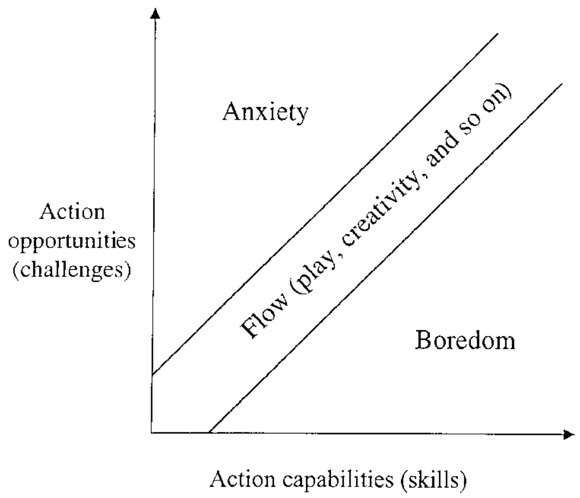


Figure 3.1: The original model of the flow state (source: [25]).

to the flow state model [25], it is a matter of finding the right balance between the challenges offered to the player and the skills he needs to complete them (cf. Figure 3.1). Then the analysis should help understanding if the task needs some specific skills or competences, if it requires time to be executed, if the user has to be physically in a specific location, etc. Those are all hints about the task difficulty, which in turn can help deciding whether to choose a GWAP approach or a Gamification approach, or even to exclude both of them. Indeed, task complexity is crucial not only to tailor the best application type, but it also heavily affects user engagement: it is well known that solving simple tasks requires only "motor skills" (which are less expensive for the brain) while solving hard tasks requires also "cognitive skills" (which are biologically more expensive); it was demonstrated that both mice (in neuroscience experiments) and men (among crowdsourcing workers) prefer the former to the latter [19].

If the atomic task is simple enough, the third question would be: *which type of data linking does my problem fall into?* While, generally speaking, any type of data linking introduced in Section 3.2 can be addressed via Gamification, adopting a GWAP approach is not always possible or recommended. As a rule of thumb, we can say that for the collection or creation cases the Gamification approach is usually to be preferred, while for the ranking or the validation cases the GWAP approach can be used.

In the case of GWAP for ranking or validation, then the final question would be: *can the players' answers be directly compared during gameplay?* This is because our GWAP enabler implements a double-player game mechanics to realize the so-called output agreement game as defined in [31]: a pair of randomly assigned players, which are not allowed to communicate, score in the game only if their outputs match when given the same shared input.

The aforementioned questions, together with other suggestions, will be part of the guidelines to support citizens to develop their solutions out of our game enablers.

### 3.3.2 Structure of the application templates

As mentioned above, our game enablers include some software building blocks to start with. Those building blocks are template Web applications that provide the basic functionalities to be customized in any specific application.

The two templates consist of three main parts, as most Web applications: the User Interface (UI), the Application Programming Interface (API) and the Data Base (DB). In the following, we give

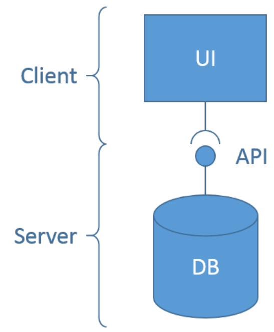


Figure 3.2: Basic structure of a game enabler

some details about those three components for each of the two game enablers, explaining how to customize them for a specific application.

**Gamification enabler**. This type of application has the goal to collect resources and/or create links, according to the data linking problem terminology. To achieve this goal, a workflow of atomic tasks is presented to the user and he is asked to execute it. The tasks inside a workflow can be ordered and each task can be set as mandatory or optional. Tasks can be of different types and the type determines the input controls presented to the user. An exit condition can be set on each workflow instance, to specify the maximum number of different users required to contribute on the same resource.

The DB of this application template contains the basic information to run the collection/creation workflows. Therefore the DB includes the following main tables:

- the list of task typologies, each one corresponding to a view in the UI; currently the enabler offers three task typologies: insert (to collect textual contributions), translate (to convert a text from one language to another) and upload (to provide media contributions, like pictures)
- the list of the tasks that compose a workflow; each task is described with several characteristics including its position/order in a workflow and its mandatory/optional nature
- the list of the completed tasks, each one consisting of a reference to the contributing user, a timestamp and the actual contribution provided by the user
- the list of gamified rewards for task completion; this is used to motivate and engage users with gamification

The API main methods are:

- retrieve the resources requiring a contribution; this can be used in case the user is allowed to choose the resources to work with
- retrieve an available workflow with its tasks; this is the method that triggers the actual contribution
- complete a task with the input data from the user; this is used to persist the user contributions collected through the application

The main functionalities of the UI are:

- show a wizard representing the workflow where each step corresponds to a task

- change the view with the input controls needed to execute a task, based on the type of task that is actually displayed
- assign a reward on the basis of user contributions

To create an instance of application out of this template, the developer should add the tasks and design the workflow, which mainly impact the content of the DB; in case, the API methods could be tailored to access the DB as needed; finally, the UI should be customized with the desired look and feel and, in case, the UI control could be extended to allow for additional types of tasks.

**GWAP enabler**. This type of application has the goal to rank or validate links, according to the data linking problem terminology. To achieve this goal, a set of links is presented to a pair of players which are asked to select the correct one with respect to a given question; if they agree on the answer, they gain points in the game. They are given limited time to answer as many questions as they can to obtain more points and they get more points for consecutive right answers. When the two players agree, the score of the selected link is incremented according to a formula that includes players' reliability (cf. Section 3.1). Our enabler includes some predefined formulas to update link scores according to the type of problem (ranking or validation).

The DB of this application template contains the basic information to run the game. Therefore the DB includes the following main tables:

- the list of the available resources representing the subject or the object of a link
- the list of the available predicates to connect subjects and objects
- the list of links between resources, each one with its score; in case of link validation, the links with a score below the threshold are to be validated by the GWAP, whereas the links with a score greater than the threshold can be considered true

The API main methods are:

- retrieve the set of links to be shown to players in each game round
- update the score of the link, according to the agreement/disagreement of players
- update the points of the players, to build leaderboards and assign badges

The main functionalities of the UI are:

- display the game task, with the links to be validated/ranked, the game timing, the action controls, etc.
- give feedback about the agreement/disagreement between the two players on the given answer
- compute the points gained by the players
- visualize leaderboards, badges, etc.

To create an instance of application out of this template, the developer should add the resources and the links to the DB; in case, the API methods could be tailored to take into account different game mechanics; finally, the UI should be customized with the desired look and feel and the specific game elements rewards (points, badges, leaderboards, etc.) could be modified to give the game a specific flavour or mood.

# 4. Gamifying LPI 7: European Cities at Night

In this chapter, we introduce the 7th Light Pollution Initiative of the STARS4ALL project: in Section 4.1 we present the current status of the Cities at Night Initiative and in Section 4.2 we explain how we intend to introduce gamification within this LPI.

## 4.1 Cities at Night Initiative

In this section, we introduce the Cities at Night initiative, we present some of its current challenges and we motivate why we think that gamification could bring benefits to the project.

### 4.1.1 Introduction

Cities at Night[1] is a Citizen Science project whose aim is to create a "Google maps"-style map of the world using night photographs taken by astronauts onboard the ISS. The project is classifying and calibrating those photos for scientific and research purposes on light pollution as it has been already proved that there is a direct relation about the scattered light measured from Earth with photometers and scattered light as seen from space [21].

The project has an amazing potential as these pictures represent a great opportunity of studying the light from all villages, cities, countries and continents around the world, since its range is more extensive than that from photometers and inventories. Indeed, ISS photos are color pictures with 10 times more resolution than the ones available so far. The best existing maps of the nocturnal Earth are created with data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) and the Suomi NPP with the VIIRS camera (750 m/px resolution). Whereas the images taken by the Defense Meteorological Satellite Program have a scale of about 2.7 km/pixel, those obtained by astronauts aboard the International Space Station have a better resolution depending of the lens used, reaching about 80 m/pixel.

These ISS images are new data that scientist have been unable to access until now, apart from a very recently published global light pollution map [12]. When Cities at Night Project is completed, not only we will have located way more precisely all light sources on our map, but we will also have color information to enable scientist to study for example the impact of blue vs. amber light [21, 26]. Even when in the future we will have better images taken from new satellites, we will always need ISS images to know how the Earth at night looked like before those satellites were launched.

Everybody can participate on Cities at Night through three applications:

- **Dark skies**[2]. With this application citizens can help classifying ISS pictures on the basis of their content. Thanks to 17,000 volunteers the project has already classified the first 130,000 pictures that can be checked on three maps: one with all the pictures[3], a map of auroras, sunsets and airglow[4] and a map with cities[5].

[1] `http://www.citiesatnight.org/`
[2] `http://crowdcrafting.org/project/darkskies/`
[3] `http://cdb.io/1JipdwX`
[4] `https://pmisson.cartodb.com/viz/70f92124-fa7e-11e4-b56e-0e018d66dc29/public_map`
[5] `http://cdb.io/1AZXsCd`

- **Lost at Night**[6]. Once images depicting cities are classified, volunteers are asked to locate them, i.e. to link them to a specific city. Thanks to the image metadata, we know where the ISS was located when the picture was taken, so we know the city should be in a 500 km area around the ISS nadir. With that approximated starting location, our volunteers have located more than 2,500 images.
- **Night Cities**[7]. When we know the city location, we need a more detailed georeferencing process. With this process, the volunteers are asked to position the image onto a physical map, by linking photo pixels to actual latitude-longitude pairs. We currently have more than 1,000 geo-referenced images to check and play with.

### 4.1.2 Challenges in Cities at Night

The Cities at Night project needs a constant flow of contributions, in order to keep up with the stream of photos continuously provided by the ISS astronauts. Herefater, we summarize the main challenges of the three applications.

**Dark skies**. Automatic classification of images require sophisticated artificial intelligence algorithms and potentially also great computing power. On the other hand, human eyes recognize right away if the camera was pointing at a city or just at the stars. So far only one artificial vision project on ISS images has achieved some classification result, but the error rate was too high [27]. Currently, an international competition was launched to provide an automated classifier able to emulate human classification skills[8].

**Lost at Night.** This application require users to find the right orientation of the image, as well as to perform some pattern recognition to identify the city. This kind of task is quite challenging as it requires quite an effort in terms of both time and skills. In fact, we noticed that this is the application with the lowest engagement rate; therefore, it should be improved somehow to reach Cities at Night goal. The users should get a reward that re-pays their contributions, otherwise they will not stay engaged in the long term.

**Night cities.** Even when the city is identified, that is not enough for scientific research on light pollution. To actually help scientists, pictures should be correctly geo-referenced, by identifying corresponding pairs of photo pixels on the one hand and latitude-longitude points on the other hand. This task is impossible to achieve automatically, since an artificial intelligence algorithm would require correctly geo-referenced images to use and compare with ISS images. This kind of task is also quite challenging for users, even if, when the city is correctly located, the task is facilitated and definitely easier than the one of Lost at Night.

### 4.1.3 The need for Gamification in Cities at Night

Thanks to the help of NASA, ESA and ASC-CSA, the news about Cities at Night has been spread and the project got plenty of volunteers. Nonetheless, the engagement rate of participant users is quite low due mainly to lack of design, usability and gamification, as well as the challenges listed in the previous section.

The design of proper incentive mechanisms is of utmost importance to engage and retain users. For example, several studies show that proper feedback information, entertaining features or public recognition can be adopted to increase engagement and to reduce churn rate.

Therefore, we think that introducing gamification in Cities at Night could contribute and bring positive effects on volunteers:

[6] `http://crowdcrafting.org/project/LostAtNight/`
[7] `http://crowdcrafting.org/project/darkskies/`
[8] `https://www.crowdai.org/challenges/2`

- Volunteers can get a sense of recognition for their contribution by getting badges, levels, certificates or appearing on a ranking or leaderboard.
- Users' motivation can be maintained over time by setting objectives and challenges, like classifying 100 pictures or being the top user finding cities on their country or continent. Indeed, local knowledge of an area is very important when locating a city and the motivation of being recognized as a "local expert" could prove to be successful (currently Cities at Night does not allow to choose a specific area).
- Social incentives can be better leveraged, e.g. letting people compare their scores with their Facebook friends or share their achievements on main social media channels (e.g., Twitter, Facebook, Google+). It is known that nocturnal pictures taken by astronauts are very popular on social media, thus a social sharing mechanism could even get new users.

## 4.2 Gamification of Cities at Night

Starting from the analysis of the Cities at Night Citizen Science campaigns, on the basis of our experience on designing games with a purpose and gamified applications, we started thinking how to introduce entertaining features. In this section, we explain in details the design and current implementation status of the gamified version of Dark Skies, which lends itself to become a Game With a Purpose. Since the basic task of Dark Skies is image classification, we can think of it as a case of linking photos to predefined categories, hence in line with the data linking problem and our game enablers as introduced in Chapter 3.

Regarding the other two Cities at Night applications, since the respective human tasks are quite difficult, we believe that introducing game incentives could only bring partial improvements, because making it a game does not make the assignment effortless. Still, in the rest of the project, we will continue our investigation on their possible gamification.

### 4.2.1 Design of Dark Skies ISS Game

As in Dark Skies, the goal of Dark Skies ISS Game is to classify the ISS images made available by NASA. The pictures have to be classified into 6 categories: "Black", "City", "Stars", "Aurora", "Astronaut" and "None of these". The game mechanism is very simple: an image is shown to the player which has to choose the right category among the ones proposed by the game, as shown in Figure 4.1.

The game is based on a double-players mechanism, according to which you play *with* the other user and *not against* him: if the two players agree on the same answer they both get points, otherwise they do not gain any points and are notified about the other player's choice. Since players do not know each other and they are not allowed to communicate, the players are encouraged to select the right category in order to get points in the game. This mechanism is inspired by the ESP game [30] designed by Luis Von Ahn, in which players have to provide meaningful labels for images to help determining their contents. Also in the ESP game players do not know each other and therefore they have to guess what their partner is typing for each image. This force them to type something related to the common image.

As regards the gamification aspects, we design the game using some game elements as playful incentives to engage users. They includes points, badges and leaderboard. In each round all the points gained from each agreement are summed up and then added to the overall score of the user. Gaining points in different rounds let the player climb the leaderboard and obtain badges. Each round lasts a fixed time (i.e. 100 seconds). Therefore, the faster the player answers, more images he can classify and more points he can gain.

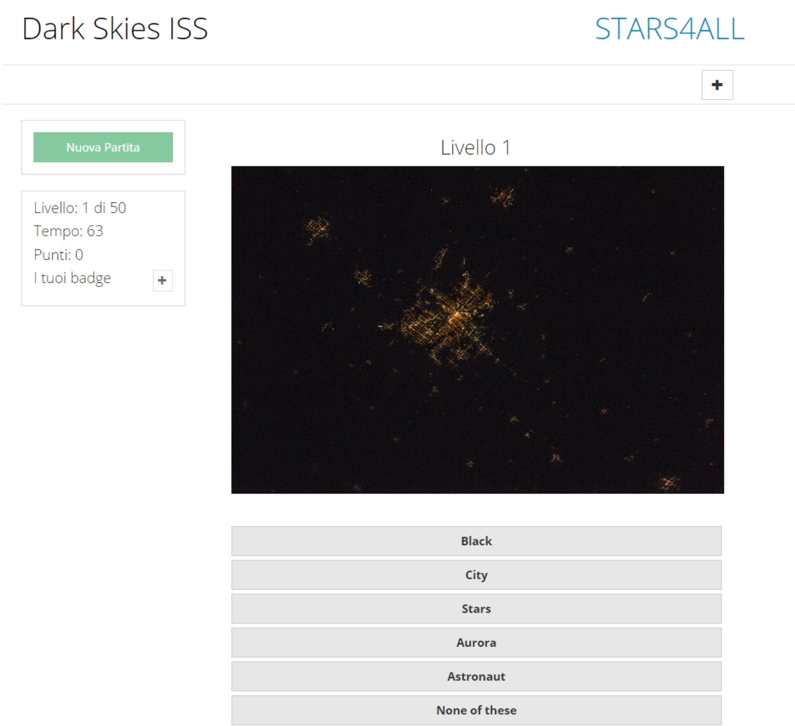


Figure 4.1: Dark Skies ISS Game: select the correct category of the picture.

Since we do not know the correct category of each picture, we need a mechanism to cross-validate all the answers given by the different players. Our enabler is able to suitably manage this situation: through the *link creation* process (in particular the *classification*), the link between a picture and a category is created; then, this link is validated using the *link validation* process by updating the score of the link and by comparing the new score with a given acceptance threshold. A score that goes beyond the threshold indicates that the link is considered true by the population of humans; we consider it as a good estimation of the actual truth value of the classification.

In the calculation of the score we want to take into account the reliability of the player, giving more importance to data coming from trustworthy users and ignoring random answers. We calculate the reliability parameter by evaluating the classification given by the user on a set of ground truth images, for which we know the correct classification. In each round, one image out five is a ground truth image, so that we can have, on average, two-three pictures on which computing the reliability value.

### 4.2.2 Implementation of Dark Skies ISS Game

The Dark Skies ISS Game is implemented as an instane of our GWAP enabler (cf. Section 3.3). It is a Single Page Application (SPA), i.e. a web application made of a single web page, which retrieves all the code in the first page load and then dynamically obtain the needed resources in response to the user's interactions. In this way the player can perceive a more rich and seamless user experience.

We developed the client-side UI with AngularJS, a very popular javascript-based open-source framework, developed by Google. The framework is based on the model-view-controller (MVC) pattern and its most notable feature is the bidirectional data-binding: the automatic update of the view when the model changes and vice versa.

The server-side API is implemented in PHP, another very popular and open-source C-like scripting language, while for the data storage we use MySQL, a very widespread database management system (DBMS), open-source as well. Data is exchanged between client and server using JSON format.

If, on the one hand, the SPA approach moves the application logic from the server to the client – and that is the case for the game general dynamics – on the other hand, the enabler's re-usability nature brings the implementation of the game specific rules to the server-side. In particular, we adopted the approach of implementing the game specific logics in the SQL queries onto the DB, so to leave the main core of the enabler very generic to be reused as much as possible in different games. On the contrary, the most tailored parts, like UI look & feel and data retrieval, can be fully customized and tuned by the developers.

### 4.2.3 Evaluating Dark Skies ISS Game

The first step of the evaluation of Dark Skies ISS Game will consist in calculating the traditional metrics defined for the assessment of GWAPs. The set of metrics for determining GWAP success includes *throughput*, *average lifetime play (ALP)* and *expected contribution* [31].

The *throughput* of a GWAP is defined as the average number of problem instances solved per human hour. The higher the throughput the more effective the GWAP. However, a GWAP with a high throughput that fails to attract and keep players is useless. Since a GWAP is a game, "fun" must also be included and measured in terms of how many people want to play the game. Since the enjoyability is difficult to quantify and depends on the precise design of each game, the *ALP* index has been defined as a proxy for the intangible enjoyability of the GWAP. ALP is defined as the overall amount of time the game is played by each player, averaged across all people who have played it. To give some reference numbers, an example of successful GWAP – the ESP game [30]– has a throughput of 233 problem instances solved per human-hour and an ALP of 91 minutes. These two metrics can be summarised into a unique measure, the *expected contribution*, which describes the overall GWAP quality. It is calculated by multiplying *throughput* and *ALP*. By merging information about how many problems are solved per human-hour and how much time a player is expected to spend in a game, the *expected contribution* indicates the average number of problem instances a single human player can be expected to solve by playing a particular game.

In addition to these quantitative and general statistics, further qualitative information will be collected by asking players to answer to game-specific questionnaires. Customized questionnaires can be designed to collect data about the game-play experience, the game enjoyment and other game context-related information (such as the previous knowledge or personal interest about the game topic). This information, combined with the traditional evaluation indexes described above, can allow the analyst to designed more complex and specific analyses about the engagement and effectiveness of the game; for example, segmenting the players according to some discriminative dimensions can lead to more specific and accurate assessments.

As explained in the sections above, *Dark Skies* and *Dark Skies ISS Game* are two projects designed to solve the same task, i.e. classifying the stream of photos continuously provided by the ISS astronauts. Therefore, it is reasonable to compare the results obtained by these two analogous methods, in order to detect potential differences or commonalities in terms of both classification results and task efficiency. Since the key difference between the two applications is the presence of gamification elements in Dark Skies ISS Game, a comparative analysis will help assessing if the presence of game elements affects performance. In particular we can evaluate if the gamification impacts on the number of engaged users or the overall effort spent by each user. Furthermore, if possible, we will asses the efficiency of the two processes, by evaluating the average time required to classify and validate each picture.

# 5. Gamifying LPI 4: Detecting Inefficient Outside Lighting

In this chapter, we introduce the 4th Light Pollution Initiative of the STARS4ALL project: in Section 5.1 we explain the rational and previous citizen science initiative to address the issue of detecting inefficient lighting and in Section 5.2 we sketch our initial ideas about the introduction of game elements in this LPI.

## 5.1 The problem of inefficient lighting

### 5.1.1 Introduction

Artificial light at night (ALAN) is an indispensable tool for human activity after the onset of darkness, but the real requirements for lighting are not entirely known yet. ALAN can increase safety and security or highlight the beauty of sites. However, where light is easily accessible and inexpensive, its use can be exaggerated and a great disturbance for others. The illumination of the nightly hemisphere is globally increasing at a rate of 3-6% per year [17], we have to expect an ongoing transformation of nightscapes in the future with the consequence that the luminance of a cloudy night in urban areas can be up to thousands of times brighter than natural [22, 12]. This insidious trend needs public awareness and collaborative solutions in order to protect the view on the stars, ecological communication, wildlife and habitat as well as human well being. Schroer and Hölker in [28] summarize important steps to reduce the negative impact of ALAN:

1. Outdoor lighting needs shielding to guide the light to target objects and areas and reducing stray light into neighbouring habitat or the atmosphere. Furthermore, the shielding prevents blinding of road users.
2. The emitted colour can have crucial input on light pollution. Often modern, energy-efficient light is used in too high intensity and with great ratio of short wavelengths. This blue part of the spectrum will scatter in the atmosphere more than longer wavelength radiation such as green and red light [1].
3. Both high intensity of lighting and inappropriate shielding can increase glare and thus reduce the benefit of the lighting.
4. A lot of lighting is left unnecessarily on, without use for most part of the night. Methods to reduce the detrimental effects of artificial light at night on nature can be inexpensive and easy to implement.

Often, only the lack of awareness is responsible for the obtrusive light and glare, too high intensity or the wrong choice of the illuminant. LPI 4 aims at creating a European dynamic map of inefficient lighting system, not to denounce or punish wrong behaviors, but to share knowledge and support awareness on how to save energy, and how to protect nature and human well-being with the most appropriate way of lighting.

### 5.1.2 Citizen science initiative to voluntarily collect inefficient lighting information

The environmental monitoring of the multiple effects of increasing ALAN worldwide requires trans-disciplinary and supra-regional research approaches. Citizen Science can contribute to the scientific mapping of the anthropogenic signal, by involving people with multiple expertises simultaneously at various sites worldwide and by increasing public awareness and outreach. At the same time, public awareness is necessary for the identification of inefficient lighting and to reduce ALAN applications, which disturb sensitive ecosystems or have potential negative impacts on the society. In a German national Citizen Science project coordinated by the IGB, citizens were asked to fill in a questionnaire about the outdoor lighting situation.

This project hypothesized that $CO_2$-concentrations and microbial diversity in freshwater water bodies are impacted by ALAN. Citizens were asked to take sediment samples at the next freshwater body closest to their home. A questionnaire was added to record the number of visible light sources, the distance to the next light source and the estimated intensity at the sample site. Further questions regarded the quality of the outdoor lighting, the lamp cover, its form and maintenance condition and the color of the emitted light (Fig. 1). The Citizen Science data was compared to a control measurement, using satellite sensing data of the Visible Infrared Imaging Radiometer Suite Day-Night Band (VIIRS-DNB). The VIIRS camera takes images of the entire Earth at around midnight local time and detects anthropogenic lighting up to a limit of 0.2 nW/cm$^2$sr [10].

Out of 636 participants from all over Germany, 96% returned the questionnaires with information about visible artificial light sources. The sample sites were distributed from natural dark areas to suburbs with variable levels of upward radiation. 1% of the questionnaires had recorded outdoor lights in areas in which the VIIRS-DNB did not detect any radiation of light. These records might be temporary lighting, being switched off when the VIIRS-data was taken, or the emitting color spectrum was outside the camera sensitivity (<500nm). For more than half of these records the emitting spectrum was indicated as white colour. White light emitting diodes (LED), for example, have considerable high emission in the range 450–480 nm and thus might be underestimated by the VIIRS-DNB sensor. Overall, the citizens' responses were rated as a useful tool to gain detailed information about outdoor illumination and the recordings matched the satellite data.

| **1. Decription of the locality** | | |
|---|---|---|
| GPS coordinates | **Lat.:** | **Lng.:** |
| **1.1. Level of urbanisation** | | |
| **a.** Inner city | | |
| **b.** suburbal | | |
| **c.** industrial | | |
| **d.** rural village | | |
| **e.** rural outside villages | | |
| **f.** protected area (e.g. nature park) | | |
| **1.2. Why did you choose this location?** | | |
| **a.** unbefitting to the architecture | | |
| **b.** inept lamp type | | |
| **c.** unbefitting to the landscape | | |
| **d.** careless energy consumption | | |
| **e.** careless with sensitive species (e.g. insects) | | |
| **2. In what distance is the lamp to the objective 1.2.?** | | |
| **a. Less than 5m** | | |
| **b. 5-10 m** | | |
| **c. 10-20 m** | | |
| **d. 20-50 m** | | |
| **e. More than 50 m** | | |
| **3. How many light sources are of concern** | | |
| **a. Over 10** | | |
| **b. 5-10** | | |
| **c. 1-5** | | |
| **d. 1** | | |

| **5. Degree of lamp cover:** | |
|---|---|
| **no cover, globe lamp** | |
| **less than horizontal cover** | |
| **horizontal cover** | |
| **full cover** | |
| **6. Description of the lamp:** | |
| **6.1. form** | |
| **a. convex** | |
| **b. straight** | |
| **6.2. texture** | |
| **a. clear, transparent** | |
| **b. frosted** | |
| **7.3. maintainance condition** | |
| **a. clean** | |
| **b. lightly dirty (< 1/4 staining)** | |
| **c. severely dirtied (> 1/4 staining)** | |
| **8. What color does the light reflect from a white sheet?** | |
| **a. yellow** | |
| **b. warm white** | |
| **c. white** | |
| **d. cold white** | |
| **e. blueish** | |

Figure 5.1: Lighting quality questionnaire of the CS project "Tatort Gewässer" (source: IGB).

## 5.2 Towards the gamification of inefficient lighting detection

The problem of detecting inefficient lighting can be approached at two different levels. At a city scale, the light pollution is related to the number of lighting sources set up in streets and squares; indexes as the average distance between lampposts or the density of street lights can be calculated and analysed. At a lamppost level, an analysis of the characteristics of each street lamp can be performed, by extracting information about the colour of the light or the orientation of the luminous flux as well as the shape of the lamp.

In both cases, a preliminary operation is the positional mapping of the existing lighting sources. Asking citizens to physically go around the city and collect data about street lamps using sensors (embedded in their smartphones or dedicated photometers) would be the obvious choice, but not necessarily the most efficient and effective solution. This option would require the participation of a lot of people performing the task in the same area and in the same period of time. Indeed, for data validation reasons, multiple measurements for each resource are required. Therefore, even if Volunteered Geographic Information (VGI [15]) is on the rise, this pure Citizen Science approach could lead to poor or partial data coverage.

For this reason, we think that it would be better to decouple the task of mapping the appearance of streets from the individuation and characterization of street lights: while the former requires the physical presence, the latter can be done off-line, thus removing the constraint of the spatio-temporal presence to accomplish this crowdsourcing task.

Street-level pictures currently available on the Web are taken during the day, as the ones provided by Google Street View[1]; usually it is harder to find pictures taken during evening/night hours when street lamps are switched on.

Therefore, we think that the first step of this Light Pollution Initiative is to set up a campaign for collecting pictures of the urban environment during dark hours. For example, we can rely on the Mapillary[2] service which is an application for sharing geotagged photos. The aim of Mapillary is to represent the whole world (not necessarily only streets) with photos using crowdsourcing. Specifically, citizens are asked to take pictures and then the Mapillary software puts them together in order to create a street-level representation of the mapped world.

In terms of the use cases we described in Chapter 3, this task corresponds to the resource/link collection process, in which citizens are asked to collect the resources (pictures) that will be next used for link creation/ranking/validation processes. It is worth noting that Mapillary has currently no gamification, so if a gaming incentive is needed, Mapillary alone could not be enough; to this end, the gamification enabler (cf. Section 3.3) could be extended to work together with the Mapillary app.

Once these pictures are collected, the second step would be to design some games – either gamified Citizen Science campaign or GWAPs – to extract light pollution information both at street-level and at lamppost-level. In this case, the same pictures can be given to multiple players so to get also results' cross-validation.

From pictures, first the number and positions of the lampposts can be identified. This could be done for example through a double-player Game With a Purpose as the one sketched in Figure 5.2, in which users must identify the part of the image in which a lamppost is depicted. This kind of game would therefore implement both a *resource/link collection* (i.e. the picture areas would be the new resources) and a *link validation*, because the agreement between players would represent a means to assess the actual correctness of the collected information. The output of this kind of application would be an estimation of the density and possibly the average distance between lampposts in a given city.

[1] Cf. `https://www.google.com/maps/streetview/`.
[2] Cf. `http://www.mapillary.com/`.

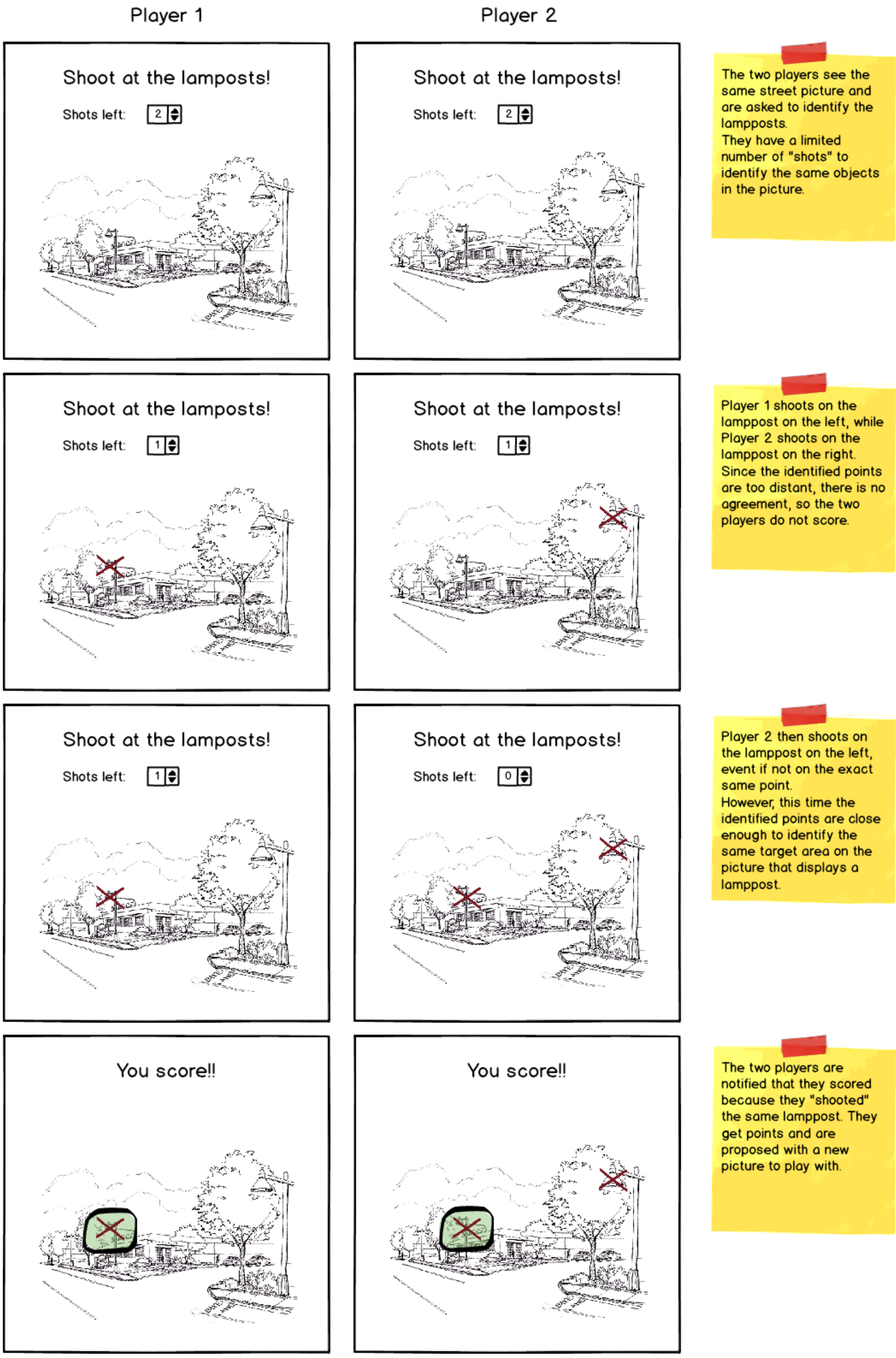


Figure 5.2: Possible gameplay to identify lampposts in street pictures.

Once identified, the lampposts could then be annotated and enriched with additional information. For example, users could be asked to characterize the lampposts along the features that were included in the questionnaire depicted in Figure 5.1: lighting quality, lamp cover, lamp form, light direction, color of the emitted light, etc. Of course, those features are not equally derivable from a street picture and some of them are identifiable only in the case of night-time photos, i.e. when streetlamps are switched on.

The enrichment of lamppost information can be considered a case of *link creation* (i.e. connecting a lamppost as a subject resource to a feature as an object resource, cf. Section 3.1). If the application is designed so to take into consideration the agreement between multiple contributors (e.g. a classification GWAP with double-player mechanics, similar to the Dark Skies ISS Game introduced in Section 4.2) also a *link validation* problem can be solved.

It is worth noting that, in order to design a gamified Citizen Science campaign or a GWAP to classify and characterize lampposts, the game enablers introduced in Chapter 3 can be leveraged; still, given that in some cases the user should be instructed on how to address the task (e.g. recognizing the emitted light's color), this kind of application should be carefully designed, on the one hand not to be too hard and on the other hand not to be too boring.

With this regard, it is possible that, in the end, those gamified campaigns collect information about *what is perceived as inefficient lighting by people* rather than an objective account of which lights are actually inefficient; in this case, the campaigns would lead to gain insights of the general perception of illumination and the general interest in lighting. Even if not directly useful to "measure" light pollution, people's perception is nonetheless an interesting result, because it can help to better plan communication and organize educational material to create awareness about the light pollution issue.

Moreover, apart from collecting and characterizing lampposts, a similar approach could be adopted to identify any source of inefficient lighting in cities, like shop signs or advertisement stalls. In this case, specific attention should be devoted, on the one hand, to discourage negative and malicious behaviours by identifying conflicts of interest (e.g. people defaming or unjustly accusing their own competitors for inefficient lighting) and, on the other hand, to put emphasis on positive results (e.g. motivating people to change their lighting to avoid pollution through rewards and recognition).

# 6. Conclusions and next steps

This deliverable reported about the introduction of gamification in the project's LPIs. After an introduction on the various methods and techniques (cf. Chapter 2), we illustrated the objectives of the game generic enablers that we are developing (cf. Chapter 3); moreover, we also summarized the current status and the plans for the introduction of gamification in two of the project LPIs (cf. Chapters 4–5).

The next two deliverables related to objective O4.1 "Implement Gamification" are D4.6 "Games Release (initial release)" (expected date: September 2016) and D4.10 "Games Release (final release)" (expected date: June 2017); they will consist of the actual implementation, on the one hand, of the generic game enablers introduced in this document and, on the other hand, of the various gamification efforts related to the project LPIs and especially LPI 7 and LPI 4. Those deliverables will realize the tasks T4.2 "Implementation of LPI & CAs game applications" and T4.3 "Gamification Analysis", the latter of which will be aligned with the crowdsourcing activites' validation of WP5.

With specific regards to the software applications described in this document at design level, reasonably we can plan that the Dark Skies ISS Game (cf. Section 4.2) as well as an initial implementation of the game enablers (cf. Section 3.3) will be included in D4.6, while the gamification of inefficient lighting detection (cf. Section 5.2) together with the improved implementation of the game enablers will be part of D4.10.

# Bibliography

[1] Martin Aubé, Johanne Roby, and Miroslav Kocifaj. Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility. *PloS one*, 8(7):e67798, 2013.

[2] Tim Berners-Lee, James Hendler, Ora Lassila, et al. The semantic web. *Scientific american*, 284(5):28–37, 2001.

[3] Maria Antonia Brovelli, Irene Celino, Monia Elisa Molinari, and Vijaycharan Venkatachalam. Land cover validation game. In *FOSS4G Europe*, 2015.

[4] Irene Celino, Dario Cerizza, Simone Contessa, Marta Corubolo, Daniele Dell'Aglio, Emanuele Della Valle, and Stefano Fumeo. Urbanopoly–a social and location-based game with a purpose to crowdsource your urban data. In *Privacy, Security, Risk and Trust (PASSAT), 2012 International Conference on and 2012 International Confernece on Social Computing (SocialCom)*, pages 910–913. IEEE, 2012.

[5] Irene Celino, Simone Contessa, Marta Corubolo, Daniele Dell'Aglio, Emanuele Della Valle, Stefano Fumeo, and Thorsten Krüger. Linking smart cities datasets with human computation–the case of urbanmatch. In *International Semantic Web Conference*, pages 34–49. Springer, 2012.

[6] Irene Celino, Simone Contessa, Marta Corubolo, Daniele Dell'Aglio, Emanuele Della Valle, Stefano Fumeo, Thorsten Krüger, and Thorsten Krüger. Urbanmatch-linking and improving smart cities data. In *LDOW*, 2012.

[7] Irene Celino, Andrea Fiano, and Riccardo Fino. Analysis of a cultural heritage game with a purpose with an educational incentive. In *International Conference on Web Engineering*, pages 422–430. Springer, 2016.

[8] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: defining gamification. In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*, pages 9–15. ACM, 2011.

[9] Damien Djaouti, Julian Alvarez, and Jean-Pierre Jessel. Classifying serious games: the g/p/s model. *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches*, pages 118–136, 2011.

[10] Christopher D Elvidge, Kimberly E Baugh, Mikhail Zhizhin, and Feng-Chi Hsu. Why viirs data are superior to dmsp for mapping nighttime lights. *Proceedings of the Asia-Pacific Advanced Network*, 35:62–69, 2013.

[11] Enrique Estellés-Arolas and Fernando González-Ladrón-de Guevara. Towards an integrated crowdsourcing definition. *Journal of Information science*, 38(2):189–200, 2012.

[12] Fabio Falchi, Pierantonio Cinzano, Dan Duriscoe, Christopher CM Kyba, Christopher D Elvidge, Kimberly Baugh, Boris A Portnov, Nataliya A Rybnikova, and Riccardo Furgoni. The new world atlas of artificial night sky brightness. *Science Advances*, 2(6):e1600377, 2016.

[13] Ivan P Fellegi and Alan B Sunter. A theory for record linkage. *Journal of the American Statistical Association*, 64(328):1183–1210, 1969.

[14] Alfio Ferrara, Andriy Nikolov, and François Scharffe. Data linking for the semantic web. *Semantic Web: Ontology and Knowledge Base Enabled Tools, Services, and Applications*, 169, 2013.

[15] Michael F Goodchild. Citizens as sensors: the world of volunteered geography. *GeoJournal*, 69(4):211–221, 2007.

[16] Juho Hamari, Jonna Koivisto, and Harri Sarsa. Does Gamification Work? – A Literature Review of Empirical Studies on Gamification. In *HICSS Conference*, pages 3025–3034. IEEE, 2014.

[17] Franz Hölker, Timothy Moss, Barbara Griefahn, Werner Kloas, Christian C Voigt, Dietrich Henckel, Andreas Hänel, Peter M Kappeler, Stephan Völker, Axel Schwope, et al. The dark side of light: a transdisciplinary research agenda for light pollution policy. *Ecology And Society*, 15(4):13, 2010.

[18] Jeff Howe. *Crowdsourcing: How the power of the crowd is driving the future of business.* Random House, 2008.

[19] Panos Ipeirotis. On Mice and Men: The Role of Biology in Crowdsourcing. In *Keynote talk at Collective Intelligence 2012*, 2012.

[20] Alan Irwin. *Citizen science: A study of people, expertise and sustainable development.* Psychology Press, 1995.

[21] Christopher Kyba, Stefanie Garz, Helga Kuechly, Alejandro Sánchez de Miguel, Jaime Zamorano, Jürgen Fischer, and Franz Hölker. High-resolution imagery of earth at night: new sources, opportunities and challenges. *Remote sensing*, 7(1):1–23, 2014.

[22] Christopher CM Kyba and Franz Hölker. Do artificially illuminated skies affect biodiversity in nocturnal landscapes? *Landscape Ecology*, 28(9):1637–1640, 2013.

[23] Edith Law and Luis von Ahn. Human computation. *Synthesis Lectures on Artificial Intelligence and Machine Learning*, 5(3):1–121, 2011.

[24] Frank Manola, Eric Miller, Brian McBride, et al. Rdf primer. *W3C recommendation*, 10(1-107):6, 2004.

[25] Jeanne Nakamura and Mihaly Csikszentmihalyi. The concept of flow. In *Flow and the foundations of positive psychology*, pages 239–263. Springer, 2014.

[26] Alejandro Sánchez de Miguel. *Variación espacial, temporal y espectral de la contaminación lumínica y sus fuentes: Metodología y resultados.* PhD thesis, Universidad Complutense de Madrid, 2016.

[27] Alejandro Sánchez de Miguel, Jaime Zamorano Calvo, and José Gómez Castaño. Image classification of night time images detected from the international space station. Technical report, Universidad Complutense de Madrid, 2014.

[28] Sibylle Schroer and Franz Hölker. Light pollution reduction. In R. Karlicek et al., editor, *Handbook of Advanced Lighting Technology*, pages 1–17. Springer International Publishing, 2014.

[29] Luis Von Ahn. Games with a purpose. *Computer*, 39(6):92–94, 2006.

[30] Luis Von Ahn and Laura Dabbish. Labeling images with a computer game. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 319–326. ACM, 2004.

[31] Luis Von Ahn and Laura Dabbish. Designing games with a purpose. *Communications of the ACM*, 51(8):58–67, 2008.