



A System for Collecting Commonsense Knowledge from Children

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Abstract: People acquire commonsense knowledge through everyday interaction and sharing of daily experiences in the form of stories. For computers to provide a more engaging and meaningful interaction with their human users, such as in interactive learning environments, they must be endowed with this same collection of knowledge. However, the manual process of building and populating computer systems with an adequately-sized body of knowledge is time-consuming and tedious. One approach to address this is to crowdsource knowledge from the public.

Story Sense is an online interactive learning environment that collects commonsense knowledge from children through computer-generated stories. It caters to three types of users, namely the teachers, the children/learners, and the adults/validators. Teachers use Story Sense to define story templates and the types of knowledge that they would want to collect from the children. The system uses the story templates to create stories with blanks for children to fill-up in an interactive environment. To motivate the children to continuously use and contribute new knowledge, gamification strategies such as leaderboards and achievement badges have been included. Simple social networking techniques are also used to allow children to read and rate (or like) the completed stories of other children.

Crowdsourcing can increase the rate of knowledge acquisition dramatically. This, however, does not guarantee that the collected knowledge is useful for Story Sense to further generate stories. A validation mechanism has been put in place to allow adult users to provide scores on the knowledge given by the children in order to help the system determine when knowledge is usable and when it should be discarded. Tests conducted among adults (aged 18 and older) and children (aged 7-10 years old) showed a high satisfactory rate both in terms of the amount and the quality of knowledge that has been collected.

Key Words: commonsense ontology; knowledge acquisition; crowdsourcing, story generation; gamification



1. INTRODUCTION

Commonsense knowledge is defined as the collection of facts and information about concepts and events that an ordinary individual is expected to know in order to make sense of the world we live in. We acquire this commonsense knowledge through everyday interaction and sharing of daily experiences, usually in the form of stories.

Researchers in the field of Artificial Intelligence have recognized the importance of commonsense knowledge in the development of computer systems. They posit that commonsense constitutes the bottleneck for making intelligent machines capable of reasoning about the everyday world (Lieberman et al, 2004) the way humans do, to provide meaningful interaction with their human users, such as in interactive learning environments.

This led to various research works that involve amassing large collections of such knowledge and heuristics for use in various applications, notably the Open Mind Common Sense or OMCS¹ (Liu & Singh, 2004) for building a commonsense database from knowledge provided by the general public; CYC² (Lenat, 1995) which is a large-scale, language-independent and extensible knowledge base and commonsense reasoning engine; and the Suggested Upper Merged Ontology or SUMO³ (Niles & Pease, 2001) containing a collection of well-defined and well-documented concepts, interconnected into a logical theory. Two approaches are usually utilized – knowledge engineers (CYC and SUMO), or the public (OMCS) through crowdsourcing.

Crowdsourcing involves the collective effort of a community to supply the knowledge needed for a specific application, thus allowing the knowledge base to grow incrementally fast due to the amount of contributions from the public. Examples of systems that use crowdsourcing are Wikipedia and ConceptNet⁴, a semantic network containing binary relations between two concepts about the world that a computer may use to understand human text.

People naturally share knowledge by telling stories (Singh & Barry, 2003). This is a form of knowledge exchange we engage in right from early childhood, and over time we learn to recall, order and

organize our daily experiences as stories. Storytelling is a great way for acquiring commonsense knowledge because “it draws on a wide spectrum of understanding of situations of everyday life” (Lieberman et al, 2004).

Singh & Barry (2003) further explained the rationale behind collecting story knowledge. Two are primarily relevant to our research. First, a good story relates knowledge about the effects of an action (e.g., *a flashlight helps you see in the dark*) to problems such knowledge helps you solve (e.g., *finding the source of the sound*) to where and when such knowledge may be useful (e.g., *camping*). Second, a story focuses the reader on a specific set of characters, objects, events and their relationships, thus, making it easier for the general public to supply knowledge as stories.

In this paper, we present our work, Story Sense, which is a web-based system that collects commonsense knowledge from children with the use of children’s stories. The system includes a facility to allow adults (i.e., parents, teachers, child educators) to define story templates and the types of knowledge they wish to collect. These templates are then used to create various stories with blanks that children will fill in an interactive gamified environment. The collected knowledge from these filled-up blanks are used to increase the commonsense knowledge of the system and can be used to further generate stories, provided the new concepts that have been acquired are validated to be correct.

In Section 2, we provide a background of key theories surrounding the development of Story Sense, specifically, representation of commonsense knowledge and gamification. In Section 3, the different components of Story Sense used to collect knowledge from the children are discussed. Section 4 contains the test results and findings. The paper ends with a summary of our research and further work that can be done to improve the knowledge acquisition task.

2. THEORETICAL BACKGROUND

2.1 Commonsense Knowledge

Commonsense concepts are everyday knowledge about concepts and their interrelationships that people intuitively possess, and which allow them to understand and interact with one another. In Story Sense, a semantic ontology of commonsense knowledge containing facts about everyday life supplied by young children are

¹ <http://commons.media.mit.edu/>

² <http://www.opencyc.org/>

³ <http://www.ontologyportal.org/>

⁴ <http://conceptnet5.media.mit.edu/>



collected and stored in a representation that is largely based on ConceptNet (Liu & Singh, 2004).

ConceptNet is a large semantic graph of commonsense concepts, related through inter-lingual and free text relations (Speer & Havasi, 2012). These relations relate concepts by their lexical definitions, and through the commonsense associations that ordinary people make. Given the concept “*pencil*” for example, ConceptNet includes knowledge about the properties that define it (e.g. *IsA(pencil, writing instrument)*), as well as incidental facts about this concept (e.g. *AtLocation(pencil, school)*, *UsedFor(pencil, writing)*).

2.2 Gamification

Wightman (2010) used two factors to classify systems that crowdsource human-based computations – the users' motivation for completing the task and if the task completion is competitive. To motivate users to continuously contribute knowledge to Story Sense, gamification techniques are used. Simple social networking techniques are also used to allow children to read and rate (or like) the completed stories of other children.

Gamification applies game design techniques, concepts and mechanics to encourage people to use and adopt certain applications or processes by making everyday tasks less boring and more engaging. In computing, these boring tasks usually include completing surveys, filling out forms, or reading text from web sites. Gamification works by providing the users with the fundamental needs and desires for reward, status, achievement, self-expression and competition. Common techniques include points and rewards, levels, achievement badges and leaderboards.

Businesses have introduced gamification techniques into their processes to increase employee productivity and efficiency in the workplace, as well as to encourage the public to buy their products or avail of their services in the form of earning loyalty points that can be used to redeem rewards. In an educational environment, gamification can also be used to boost academic performance among the learners. Teachers can give “mission objectives” that are to be accomplished before the class ends. “Bonus objectives” are performed at home and to be checked during the next class session. Students are given points for completing these objectives. They can also earn merits or penalties. They can then level-up based on their accumulated performance that is

assessed at the end of the school year.

3. Story Sense

Story Sense is a web-based knowledge acquisition tool embedded in an interactive learning environment. It collects commonsense knowledge from children through computer-generated stories in order to build a large repository of commonsense knowledge. Once the contents of this repository has been validated, they can be used by other applications, such as the Picture Books story generation systems (Solis et al, 2009; Ang et al, 2011), to provide a more meaningful interaction with their human users.

Story Sense caters to three types of users: teachers, children/learners, and adults/reviewers. Similar to other crowdsourcing applications, the system has been designed with the assumption that the contributors may have no background knowledge about artificial intelligence or computer science.

3.1 Defining Story Templates

Teachers use Story Sense to define story templates and the types of conceptual relations that they would want to collect from the children. Story templates are manually drafted text files that were adopted from the works of (Chua & Ong, 2012). The system then uses these story templates to create stories with blanks for children to fill-up in the web.

A story template is made up of different components: (1) the static text of the story that will not change; (2) a set of queries that will retrieve existing concepts from the KB; and (3) numbered blanks (represented as *[n]*) that correspond to items in the story that must be supplied by the child. A sample partial story template is shown in Listing 1.

In the template, lines L1 and L2 contain queries. A query is comprised of two parts. The left-hand side of the query is a variable, represented by *\$name*, which is used to store the concept that has been retrieved from the KB. The right hand side of a query contains a conceptual binary relation or assertion of the form (*concept1, relation, concept2*).

Listing 1. Partial story template (Chua & Ong, 2012)

```
L1. <$location = (?, Is-A, "location")>
L2. <$object = (?, Is-A, "object") &
    (?, LocatedAt, $location)>
L3. I am in %$location%.
```



L4. I saw a %\$object%.

A question mark (?) symbol used in place of a concept means that the system will look for candidate concepts from the KB, given the relation name *relation* and the second concept (either *concept1* or *concept2*). For example, in Line L1, we are looking for any concept that is a location, and the KB may return *park*, *school*, *hospital* or any other concept that exists in the KB that is a location. In Line L2, we are looking for a concept that is an object and is located in *\$location* (the result from the query in L1). The ampersand (&) symbol represents a conjunction condition that must be satisfied. Assuming the first query returns the value *school* for the variable *\$location*, then the KB may return *blackboard*, *desk* and *computer*, if these concepts exist in the KB and have been tagged as objects that are located in *school*. Lines L3 and L4 contain static text as well as references to the two variables, denoted by enclosing the variables with the percentage (%) symbol.

The use of queries in story templates allow the generation of different stories from a given template. Listing 2 shows 4 possible stories that can be generated from the template given in Listing 1.

Listing 2. Possible stories

Story 1:
I am in school. I saw a blackboard.

Story 2:
I am in school. I saw a desk.

Story 3:
I am in park. I saw a slide.

Story 4:
I am in park. I saw a sand box.

Listing 3 is a continuation of the story template in Listing 1. This time, it contains partial text that requires input from the child to complete the story, as shown in the sample story text in Listing 4. Those portions of the story text that will be provided by the child are enclosed in numbered square brackets in the story template. The number is used to associate the concept to a relation template. Notice that a concept can be associated to one or

more relation templates, as seen in Lines L5 and L6.

Listing 3. Partial story template.

L5. Its color is [1,2].
L6. Its shape is [3,4].
L7. I can also describe the %\$object% as [5].
L8. A %\$object% is usually used for [6].

Listing 4. Story with blanks.

Its color is _____. Its shape is _____.
I can also describe the desk as _____.
A desk is usually used for _____.

Relation templates, again adopted from (Chua & Ong, 2012), are manually defined to match the blanks of a corresponding story template. The relation templates for the story template in Listing 3 are shown in Listing 5. The ? in a relation template will be replaced by the actual concept that the child will provide to Story Sense. Variables defined in the story template can be used in the relation template.

Listing 5. Sample relation templates.

[1] ? | IsA | "color"
[2] \$object | HasColor | ?
[3] ? | IsA | "shape"
[4] \$object | HasShape | ?
[5] \$object | HasProperty | ?
[6] \$object | UsedFor | ?

Assuming the child completed the given story by providing the concepts in Listing 6, the corresponding conceptual relations that were acquired by Story Sense are shown in Listing 7.

Listing 6. Sample completed story.

I am in school. I saw a desk. Its color is brown. Its shape is rectangle. I can also describe the desk as neat. A desk is usually used for writing.

Listing 7. Sample relations learned by Story Sense.

[1] brown | IsA | "color"
[2] desk | HasColor | brown
[3] rectangle | IsA | "shape"
[4] desk | HasShape | rectangle


```
[5] desk | HasProperty | neat
[6] desk | UsedFor | writing
```

3.2 Acquiring Knowledge from Children

From the defined story templates, Story Sense creates stories with blanks for children to fill-up in a web-based environment (see Figure 1). The child's input is then used to populate the knowledge base, allowing the system to acquire new concepts which it can later use to generate more stories.

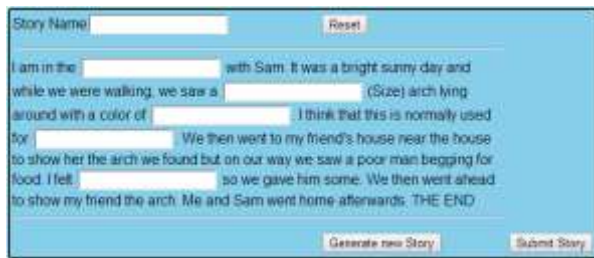


Figure 1. Story with Blanks

To motivate the children to continuously use and contribute new knowledge, Story Sense incorporates various gamification strategies, namely leaderboards, story of the week, achievement badges and level up. For these strategies to work, each user profile (Figure 2) associated with a child includes the experience points he/she has accumulated by completing stories. As the child completes more stories, he/she can level up to unlock more complex story templates. Figure 3 shows the leaderboard, arranged in decreasing points and level of the children registered in the system.



Figure 2. User Profile

Leaderboard		
Name	Level	Points
nicoloco	2	619
balagtas	1	257
sa	1	237
Yellow Four	1	180
Lk	1	175
DK	1	160
nej	1	153
Egoist	1	90
Shakespeare	1	90
allanPow	1	90

Figure 3. Leaderboard

To encourage learning through peer interaction, children can view other children's stories and "like" them. A story with the most number of "like"s for the week gets to be featured in the *Story of the Week* (shown in Figure 4). Another goal of this social networking feature is to motivate children to make good stories that can receive "like" votes from others, promoting healthy competition.

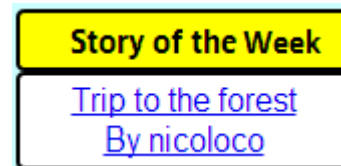


Figure 4. Story of the Week



Figure 5. Achievement Badges

A child can also accumulate different badges that others can view in his/her user profile, as shown in Figure 5. The *First Story* badge, for example, is



awarded when an author completes and successfully submits his/her first story to the website. The *Rising Up* badge is awarded when an author accumulates a certain amount of points to reach level 10. The *10 Stories* badge can be unlocked by completing 10 story templates within Story Sense.

3.3 Validating Knowledge

Crowdsourcing can increase the rate of knowledge acquisition dramatically. This, however, does not guarantee that the collected knowledge is useful for Story Sense to further generate stories. According to [3], knowledge bases built by a distributed community of volunteers require methods of assessing the quality of the knowledge that has been contributed. Thus, a validation mechanism has been put in place in Story Sense to allow adult users (called the “reviewers”) to provide scores on the knowledge given by the children in order to help the system determine when a knowledge is usable and when it should be discarded.

A reviewer can perform two types of rating – to the concept that was provided in the story blanks, and to the story quality as a whole. To validate a concept, the reviewer can give a rating of strongly disagree, disagree, neutral, agree or strongly agree (Figure 6). This rating is used to calculate a score for the story, which is later combined with scores from other reviewers to determine which story will be recognized as the *Highest Rated Story*, as well as award corresponding points to the child author that may affect his/her leaderboard status.

Knowledge	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
person Can become doctor	○	○	★	○	○
glad Results to overjoyfulness	○	○	★	○	○
glad Leads to jump	○	○	★	○	○

Figure 6. Validating Concepts

A reviewer rates a story, using his/her own subjective criteria, on a scale shown Figure 7. This serves to add bonus points for the author of the story.

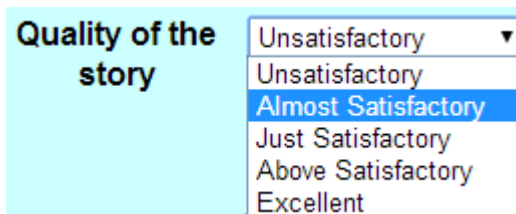


Figure 7. Rating a Story

4. RESULTS AND FINDINGS

Various testing activities, all computing rather than linguistic in nature, were performed to determine the amount of knowledge that can be gathered from children using a combined crowdsourcing and gamification approach. Reviewer validation was also conducted to determine the percentage of usable knowledge that have been acquired by the system.

4.1 Preparations for Testing

To prepare Story Sense for testing, five story templates were defined per difficulty level. There are currently four levels, leading to 20 story templates. For testing purposes, these parameters were set to low values to enable the authors (children) to unlock more levels within a shorter period of time. The values can be adjusted by the system administrator as the need arises. Furthermore, more story instances can be created from these 20 templates as the system acquires more commonsense concepts that are validated.

The difficulty level of the story templates was determined based on the types of conceptual relations that each template is targeting to learn. This categorization was based from the works of Chua & Ong (2012) and is shown in Table 1.

Generic relations (i.e., *isA*) are used to classify objects. Object relations describe the physical composition and usage of an object and includes the relations *usedFor*, *madeOf*, *colorOf*, *sizeOf*, *shapeOf* and *textureOf*. The actions that can be performed on an object is also included in this category using the relation *receivesAction*.

Character relations are used to describe characters, such as their profession and gender. Spatial Relations correspond to those describing locations and orientation, such as the location of an object, the location where an action can be performed, and co-located objects. Action relations are used to describe the causal chain of story events (i.e., *leadsTo*) and the purpose of an action.

Table 1. Categories of Relations per Difficulty Level

Difficulty Level	Conceptual Relations
1	Object and Generic relations
2	Character and Level 1 relations



3	Spatial and Level 2 relations
4	Action and Level 3 relations

Prior to testing, the ontology must also be populated with initial seed data to generate stories from which new concepts can be learned. The ontology has 362 concepts and 24 relation templates.

The duration of the testing was one week, with nine children between the age of 6 to 13 years old participating as authors. These children were not given any orientation on how to use the system; they were simply given a link to the web site and were asked to follow the online instructions.

4.2 Evaluation

Since Story Sense keeps track of all the stories completed by each of the author in his/her respective user profile. Table 2 presents a summary of the average number of stories completed within the one-week test period.

Table 2. Average Number of Stories

Test Criteria	Test Results
Ave. no. of completed stories	4.45
Ave. no. of stories with ratings	4.33
Ave. no. of “likes” given to others	1.56
Ave. no. of “likes” received	5.44

Table 3. Summary of User Experience Points

Experience Points Criteria	Ave. Values
Average difficult level	2.33
Average points acquired	512.78
Average highest score	127.67
Average lowest score	79.22

The children were able to complete at least 2 stories each, with 1 author completing as many as 11 stories. Among the 9 authors, only 3 (or 33.3%) engaged in social networking activities by reading and “liking” another author’s work.

Table 3 presents a summary of the experience points of the authors.

After crowdsourcing knowledge from 9 children, the ontology of Story Sense grew by 42.52%

(or an additional 154 concepts). Table 4 provides a summary of the size of the ontology after the testing period.

Table 4. Ontology Size after Testing

Usable assertions	710	81.61%
Unusable assertions	117	13.45%
Duplicate assertions	43	4.94%
Total assertions	870	100.00%

Table 5 shows the average score of the gamification features that the children favored, from a scale of 1 to 5, with 5 being the highest score. The social networking feature of “liking” another author’s story received the highest rating, even though only 33.3% of the participants used this feature.

Table 5. User Acceptance Scores for Gamification

Gamification Feature	Ave. Score
Liking other’s Stories	4.57
Story of the Week	4.43
Term of the Week	4.29
Achievement Badges	4.29
Story Feed	4.14
Leaderboard	4.14

5. CONCLUSIONS

In this paper, we presented the features of Story Sense, a web-based environment that crowdsources commonsense knowledge from children through stories with blanks. To motivate the children to continuously use the system, a necessary task in order to increase the knowledge base of the system, gamification techniques such as leaderboard, achievement badges and level up were used. The “like” feature commonly found in social networking sites is also available to enabled children to review and rate other children’s completed stories, thus promoting healthy competition while building vocabulary skills.

Story Sense also provides adults with two kinds of access; teachers can define story templates and relation templates depending on the types of knowledge they would want the system to acquire, or the type of concepts they would want to develop in their learners. Reviewers can validate the concepts



provided by children, and only those concepts whose validation score passed a specified threshold will be used to further generate stories.

When the reviewers validate stories, scores are given based on the validity of the concepts in the story which allow the authors to level up. As the authors level up, they unlock more story templates for them to complete. This process allows the system to have a leaderboard containing the top scorers and a section where the most popular term and featured stories are displayed based on the ratings.

One of the major limitations of Story Sense is that it is very dependent on the reviewers to validate the crowdsourced knowledge. Without the reviewers, the knowledge base of Story Sense would not grow. Grammar checking and spelling check are also not performed on the input.

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