Treasure chest

Computer Science Group - IREM of Lille

1. Once upon a time...

I was walking peacefully in the small wood behind the garden of my grandparents. It all started when I noticed a tall and thin man dressed in a guard's uniform in the middle of nowhere. I'm not used to meeting men over there, I share my sunday walks especially with animals. As I did not know this man, I ignored him and went on my way.

The man, in guard's uniform, reappeared juste in front of me. Fear made me jump ! But I felt like it was my lucky day and I shouldn't run away...« Who are you ? » I asked. The man approached me and spoke very softly as if he was giving me his very big secret : « I am the guard of the treasure chest. ». I did not understand what he was talking about. « I am the guard of the treasure chest. ». « Oh yes !!! ». Suddenly, I thought about the chests I had found the other day in the attic of my grandparents' house, by the way I didn't dare to open them.

« What do they contain ? », I was curious about their content. The guard looked amused, he was probably waiting for me to ask the question. « There is a treasure chest among bomb chests ! ». He was starting to really intrigue me. « I'm tired of guarding the chests, I wish a deserving person could find the treasure, but be careful, if you open a bomb chest, everything will explode ! ». I felt more and more interested by this story. « What can I do to find the treasure chest ? ». « Let's go see these chests together. From now on, I will answer your questions exclusively with « yes » or « no ». If you find the treasure chest then I offer you the treasure and I can free myself from this task. »

2. Student instructions

The goal of this game is to find the treasure chest without opening other chests.

One of the students is the chests' guard. He puts the treasure in one of the chests without showing the rest of the group and he holds the photo of this chest, face down, in hands. The chests' guard responds to each question exclusively by « yes » or « no » and he is obliged to answer.

The other students must agree on the questions to ask the guard and try to find the treasure.

2.1. Dialogue with the guard

You ask questions to the chests' guard who answers you exclusively by « yes » or « no ». You listen the answer and you can ask other questions one by one.

What first question can you ask him ? The guard answer allows you to eliminate how many chests ? Try to find, with a minimum of questions/answers, the treasure chest. What is this minimum number of questions ?

2.2. A letter to the guard

This time, it's time for the guard to return home, his home is very far away from where you are. But he wants to continue to help you. You can communicate with him only once by mail. You can ask as many questions as you want. He will answer all the questions, stil exclusively by « yes » or « no ».

Write on a paper the questions you want to ask him, slide the paper in an envelope that you address to the chests' guard and post your letter. Once you receive his answers, you need to guess the treasure chest !

Replay the scene until you reach a minimum number of questions to ask the chests' guard.

2.3. A more than clever guard

The guard, who is a very clever man, wants to complicate you the task just to find out how motivated you are to find this treasure chest. So he allows himself to lie at most once when he answers. You can't trust him anymore, so you need to check the accuracy of his answers and still find the treasure chest.

Can you be smater than him ? How many questions can you ask to be sure to find the treasure chest ? What is the minimum number of questions that you can ask ?

3. Scientific enlighting

3.1. Dialogue with the guard

The underlying idea is the binary search. A « right » question eliminates half of the chests.

If we can eliminate half of the chests at each question, the we are interested in the number of times that the number of chests can be divided by 2. We can prove that this method is optimal : there is no other method more efficient on average that works better. For our 16 chests, 4 questions identify the treasure chest. If we had 16 000 chests, 12 questions would be enough ; for 16 million chests, 20 questions are enough.

This method is widely used in computer science, for example to search a value in a sorted set of values : a contact in an address book, a word in a dictionnary, etc.

3.2. A letter to the guard

The underlying idea is the binary encoding of the chests.

These chests distinguish by 4 (independent) characteristics. So we can agree to designate a chest by 4 values, one by characteristic. Each caracteristic can take two values. So we can encode it by a binary digit (0 or 1). A chest can therefore be identified by a 4-digit binary number, from 0000 to 1111.

3.3. A more than clever guard

This version of the game highlights the notion of error detection/correction (Hamming code).

The answers of the guard can also be represented by a 4-digit word. If the guard lies at most once...

3.4. In the classroom

Students are encouraged to engage in a scientific process. They can observe, manipulate, experiment on the computer science notions through the game. They can replay the scene to test several solutions. They must work as a team so they develop their communication skills between peers and learn to respect others' point of view. They have to explain their approach and their choices to the group. Throughout this activity they work on the information processing, their organization and representation. They make a connection between a pseudo-real situation and its translation into mathematical and computing language.

In classroom, scientific enlighting can be reviewed with the students. They are « Concours Castor » activities that work these notions in interactive mode (in french). In french national official programs, this activity is associated with several skills : the research, the represenatation, the reasonning, the communication. More specificly, we are interested in data format identification and their reprensetation and research algorithms.

4. Animator sheet

4.1. Purpose of the activity

The purpose of this activity is to familiarize students with some computer science notions via a fun and unplugged game : binary search, binary coding, detection/correction errors.

4.2. Useful information

Used equipment and documents   For a group of 3-4 students, a box of chests is needed. On box is composed of :
- 16 chests that represent 16 different values based on 4 physical characteristics ;
- 15 bombs and a treasure to discover ;
- an envelope with the photo of each chest.

It is also necessary to distribute the introduction story, a paper and a pen to write the questions to ask to the guard.

Indicative duration :   One session of 55 minutes.

4.3. Progress of the session

How it works ?

Preparation (5 min) : The class is divide into small groups of about 4 students. Each group receives a box of chests and a student sheet (see above).

Research (40 min) : At the beginning of the session, once everyone is well installed, we let students « play » autonomously so that they discover the activities and especially so that they ask to themselves the « right questions ». At after 10 minutes of research, adults can begin to discuss with the group of students, each in turn, in order to listen to their reasoning and to propose possibly some improvements. The adults are there to provide key words on the concepts that come naturally to students.

Scientific enlighting (10 min) : At the end of the session, the groups stop playing regardless of their progress. During 10 minutes, the adult explains the computer science notions that were discovered through the game. The goal is to share students' ideas and to give them some food fof thought.

Remarks and difficulties

The main difficulty lies in the differentiated advancement of groups of students. Adults must adapt to the level and students' questions without giving them the answers. Some students may fing the « best answers » quite easily while others will not understand the meaning of the activity. No matter how quickly students work, the important thing is to enrich their thinking with the underlying computer science notions.

While playing, students can't just hope to find the treasure chest by chance. Questions can't depend on the chosen treasure chest.

4.4. Expectations from students

Dialogue with the guard

The goal is that students identify 4 questions that correspond to 4 physical characteristics of the chests to approach the binary search. If the group proposes more than 4 questions, they can be asked to try to reduce the number of questions.

Example :

- Is the treasure chest silver ?
- Does the treasure chest have a small wrist ?
- Does the treasure chest belong to the pirate ?
- Does the treasure chest have a chain ?

A letter to the guard

Students look for a way to « number » and therefore to distinguish the chests. The goal is for them to see that the 4 physical characteristics of chests are precisely what allow them to distinguish the 16 chests. The answers for this activity are similar to the first activity but we must not forget that this time the group has the guard's questions all together. The data organization is not the same. This forces the students to look for the treasure chest in a different way.

Example :

- Is the treasure chest golden ?
- Does the treasure chest have a big wrist ?
- Does the treasure chest belong to the skull ?
- Does the treasure chest have a chain ?

A more than clever guard

The goal is to let the students reflect on the detection and on the correcting errors. If the students are able to ask questions that allow them to find the guard's lie, it is OK even if the number of question is very high.

Example : Ask two times the same questions as the previous activities to see where the guard is lying and ask the same question for the third time to know the real answer.

4.5. Examples of detection errors

In this paragraph, we study an example of error detection with a maximum of 7 questions asked to the guard. The guard may lie at most one time so we may have at most one error.

The characteristics of the chests are numbered.

c1. Silver or golden

c2. Small or big wrist

c3. Pirate or skull

c4. Chain or no chain

Here are the first four questions to ask and sample answers.

1) Is the treasure chest silver ?

   Answer : Yes

2) Does the treasure chest have a small wrist ?

   Answer : No

3) Does the treasure chest belongs to the pirate ?

   Answer : Yes

4) Does the treasure chest have a chain ?

   Answer : Yes

Case : without a lie

5) Is the treasure chest silver, has a big wrist, belongs to the pirate and has a chain ?

   Answer : Yes → no lie

Remark : The answer can't be a lie because if it is, it means that the guard has already lied on one of the first four questions. But we know that the guard can't lie two times.

Case : a lie on the first characteristic (c1)

5) Is the treasure chest silver, has a big wrist, belongs to the pirate and has a chain ?

   Answer : No → a lie is detected

6) Is the treasure chest silver and has a big wrist ?

   Answer : No → the lie is about c1 or c2

7) Is the treasure chest silver ?

   Answer : No → the lie is about c1

Case : a lie on the second characteristic (c2)

5) Is the treasure chest silver, has a big wrist, belongs to the pirate and has a chain ?

   Answer : No → a lie is detected

6) Is the treasure chest silver and has a big wrist ?

   Answer : No → the lie is about c1 or c2

7) Is the treasure chest silver ?

   Answer : Yes → the lie is about c2

Case : a lie on the third characteristic (c3)

5) Is the treasure chest silver, has a big wrist, belongs to the pirate and has a chain ?

Answer : No → a lie is detected

6) Is the treasure chest silver and has a big wrist ?

Answer : Yes → the lie is about c3 or c4

7) Is the treasure belongs to the pirate ?

Answer : No → the lie is about c3

Case : a lie on the fourth characteristic (c4)

5) Is the treasure chest silver, has a big wrist, belongs to the pirate and has a chain ?

Answer : No → a lie is detected

6) Is the treasure chest silver and has a big wrist ?

Answer : Yes → the lie is about c3 or c4

7) Is the treasure belongs to the pirate ?

Answer : Yes → the lie is about c4