Imperceptible edutainment & mathematics

Introduction

Edutainment is generally seen in rather narrow context, e.g. an informal video game about teen pregnancy, a multimedia package about cancer, a point-and-click game about colors for toddlers, a geography game, etc. In this paper I want to show that some forms of entertainment can also be educational even when they are not designed to educate. I want to make clear that even an exact science like mathematics can be taught almost unnoticeable. In this paper I will give a examples of completely different games in which math comes to play, how mathematics is used to improve strategies and how those games train the cognitive skills of the player. With writing this paper I hope to prove that edutainment is everywhere and that training math can be done painless, without even fully realizing it.

The connection between games and mathematics may not be clear at first sight but there are a lot of areas where games and mathematics overlap. Mathematics are built on very simple rules, axioms. These simple rules can be used to construct complicated theorems. The same holds good for a lot of games, video games and classic games alike. There is a structure of simple, well-defined rules and those rules can be used together to form a great number of complicated strategies or patterns, ideally a winning strategy or a good pattern. Because some games can be seen as *mathematics-like* and that playing games is not seen as a boring activity, games can be used to develop a better insight in mathematics in an enjoyable way. In this paper I will cover three completely different types of games:

- **Starcraft**: a real-time strategy video-game;
- **The game of Go**: a classic board game;
- **Juggling**: the art of throwing a number of objects and catching them again.

Starcraft

Starcraft is an award winning real-time strategy game and, despite it's eight years old, is still played a lot, even by professional gamers. Starcraft is a perfect example of a game that has a few simple rules. But the use of those rules can yield refined strategies. Starcrafts architecture is very similar to a mathematical theory, a rule based system. These are the basic rules, axioms:

- There are mobile and static units displayed on the screen, these are rendered in two dimensions
- Each unit has a distinct number of properties
  - A life bar
  - Attack strength
  - A total cost of ownership measured in resources: construction time, number of resources, resources for maintenance. In the image on the right you see the resources needed to build a SCV unit and how much resources the base has

  - Speed of movement
  - Specific capabilities
- A unit is destroyed when the life bar hits zero
- A player wins when he destroys all enemies units

Any other real time strategy game has a similar set of rules but with minor variations. These rules can be combined to form a strategy e.g. creating a number of units with a certain attack points to conquer an enemy base. The professional players of real time strategy games do this intuitively. They are looking for the optimal balance between gathering recourses, building units and the best army to attack a base or other units.

Starcraft & mathematics

ABERKANE, Idriss wrote a study on videogames and mathematics: ô*Pedagogical use of videogames: the effect, acquisition of rules and understanding of rule based systems*ô[1]. He used Starcraft as an example of a rule based system, and watched an experienced gamer playing Starcraft. The player was a male economy student who had been playing Starcraft for a couple of years, some of his digital wars were videotaped and studied. It became apparent that the player developed complex strategies to win the game. The player calculated the optimal use of resources, timed the delay in reaction of his opponent when he counter attacked, studied the balance of units in the army of his opponent,é In other words he used a professional, scientific approach. On top op that, all these calculations had to be done in real-time and the decisions that follow the calculations had to be visible in-game as quick as possible: the number of actions per minute is also an important factor in winning a game. All this results in an adaptation of the players cognitive capabilities. Playing at this level becomes work: it may be perceived as a boring activity for someone who never played Starcraft.

ABERKANE concludes that the player developed a profound intelligence while playing the game: he understands the most subtitle aspects, the aspects that are far from apparent when you look at the small number of initial axioms. He learned algorithms to improve his skills and even realized that his approach is similar to a mathematician searching to invent a new theory. As it is the case with mathematics Starcraft strategies also has a number of, albeit less formal, notations. The formula that is represented below is an example of a strategy as found on www.starcraft.org. This is a complete plan for a game in the Protoss camp. The signs define what buildings to build, the + signs are spacers to define where in the map the buildings are build:

```
++++++++++++++++++++++
++++++++++[*]+++++++++
++++++++@@!@@!@@+++++++
+++++@@(=)+++++(=)@@+++
+++++@@(=)+[*]+(=)@@+++
+++++@!(=)+++++(=)@!+++
++++!@@@@@@@@@@@@@@@+++
+++(G)(G)!(G)(G)!(G)(F)
+++(G)(G)!(G)(G)!(G)(C)
+++++++++!++++++!+++(A)
+++(G)(G)!(G)(G)!(G)(T)
+++(G)(G)!(G)(G)!(G)(F)
+++++++++!++++++!+++(F)
```

Legend

[*]	= Nexus
@	= Cannon
!	= Pylon
[G]	= Gateway
(F)	= Forge
(CC)	= Cyben. Core
(A)	= Citadel Adul
(T)	= Templar Archive
+	= Square

Starcraft & edutainment

Starcraft is an entertaining game. This combined with the fact that a lot of thing can be learned while playing Starcraft makes it an edutainment package although the designers of Starcraft never labeled it as edutainment. Especially the more advanced players will learn a lot of valuable concepts: they have learned, manipulated and developed insight in a rule based system, they will be able to learn an other rule based system, like mathematics, with greater ease.

The game of Go

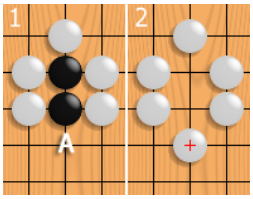
Go is an Asiatic board game with relatively simple rules, but despite the simple rules the game strategies self are more complex than those of chess. Go is, just like chess or draughts, a perfect information, deterministic, strategy game. I wanted to discuss this game because it is, just like Starcraft, a rule based system with simple rules and complex strategies. The game is so complex that the best Go computer program loses against an average Go player. Until today Go remains one of the challenges for the field of artificial intelligence. The game of Go can not be approached by brute force, not even by the most powerful supercomputers, because there are so many different possible games, much more than chess. There are $9x10^{537}$ different possible games, there are only 10^{90} protons in the visible universe [5]. Chess is a battle, Go is war.

The aim of the game is to conquer as much territory as possible by limiting the freedom of your opponent. Albeit the rules are simple there are a number of variations in some details this is mainly because it is such an old game, there are Chinese, Japanese and Korean rules. These are the basic rules, axioms as they appear on [5].

- Two players, black and white, take turns placing a stone (game piece) on the points (intersections) of a 19 by 19 board (grid). Black moves first.

- Stones must have liberties (empty adjacent points) to remain on the board. Stones connected by lines are called chains, and share their liberties.

- When a stone or a chain of stones is surrounded by opponent stones, so that it has no more liberties, it is captured and removed from the board. As shown in the image on the right.



- If a stone has no liberties as soon as it is played, but simultaneously removes the last liberty from one or more of the opponent's chains, the opponent's chains are captured and the played stone is not.

- "Ko rule": A stone cannot be played on a particular point if doing so would recreate the board position that existed after the same player's previous turn.

- A player may pass instead of placing a stone. When both players pass consecutively, the game ends and is then scored.

There is no real end to the game. Real wars end when the participants sign treaties. Likewise, in Go, the players have to agree that the game has ended. Only then are the score and the winner finally determined.

The game of Go & mathematics

The study of Go combined with mathematics has a long history. There are studies known of more than a thousand years ago. Yi Xing (672-717), Hen Gua (1030-1093) and Xuan Zong tried to solve Go problems using permutations. Today Go is still studied heavily, especially the mathematics of end-game situations is a popular subject. One of those studies is ó*Go und Mathematic*ô by Jörg BEWERSDORFF [8] in his work he tackles a number of endgame problems using minmax theory and combinatory logic. Even when you are playing Go as a hobby you are still using the same or very similar algorithms and thought flows to make your move.

Go also has a notation system, primarily used to record games and to play games over the internet but it can also be used as a mathematical tool to analyze games. This is an excerpt of the sgf format:

```
;B[qd]T[ 0];W[cd]T[ 1];B[pq]T[ 0];W[dq]T[ 1];B[cf]T[ 0];W[ec]T[ 1]
;B[fp]T[ 0];W[co]T[ 1];B[qn]T[ 2];W[oc]T[ 1];B[pc]T[ 3];W[pb]T[ 8]
…
)
```

The game of Go & edutainment

Playing Go is fun on the other hand it trains problem analysis, Concentration, memory, mathematical insights, Decision making, cognitive skills and creativity. Dr. Hans KLAUS, said this about chess:

> *ñChess helps any human being to elaborate exact methods of thinking. It would be particularly useful to start playing chess from the early school days ... Everybody prefers to learn something while playing rather than to learn it formallyé it yields an improvement in our childrens school achievements. Those children who received systematic instructions in chess improved their school efficiency in different subjects, in contrast with those who did not receive that kind of instruction."*

This is true for chess and, I believe, even more so for the game of Go. This leads me to the conclusion that Go is an edutainment package and a good one at that.

Juggling

Juggling is applied mathematics. Juggling as it is today covers a great number of different disciplines: diablo, shaker cups, devil sticks, contact juggling, fire-twirling, hat manipulation, etc. In this paper I will only cover the most recognizable form of juggling, toss juggling. Toss juggling is the art of throwing any number of objects in the air, it does not really matter what: balls, beanbags, rings or clubs and ideally catching those objects again. The idea is to form patterns in a strict rhythm. Juggling can be seen as a rule based system. There is a very small set of extremely simple axioms:

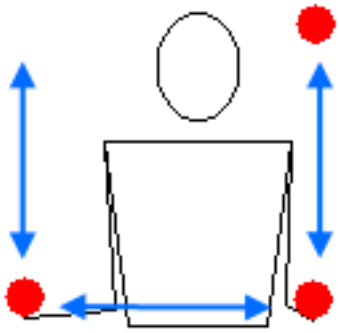
- Objects can be caught and thrown
- Only one object fits in one hand at any given time

Despite these simple rules juggling patterns can become very technical and complicated.

Juggling & mathematics

Juggling patterns can be written down exactly as a mathematical formula. There are a few different pattern notations, the most well known is the synchronous siteswap notation. The multiplex siteswap, beatmap and multi hand notation are other lesser known notation systems. Their common aim is to provide a concise and mathematical way of describing patterns. They are also used as a tool for mathematical

analysis of juggling. The multi hand notation is the most formal, complex and complete. It can be used to describe patterns involving any number of hands not necessarily throwing in an alternating manner and even to check if a pattern is *jugglable* [3]. The multi hand notation was developed by Ed Carsen for use in his computer program JugglePro. Although this notation is the most flexible it is not used often, it is too complex for most purposes. The siteswap notation is most commonly used and almost all experienced jugglers know this notation or one of its many variations. The following image shows a three ball juggling pattern called the box. Next to the image the pattern is written down in the siteswap and multi hand notation systems.



The Box

Siteswap notation: (4,2x)(2x,4)
Multi hand notation:
2x2
(1,1)(0,2)
(0,2)(-1,1)
3

There are more areas in which juggling overlaps with mathematics. Problem solving is probably the most basic and common form of mathematical activity. In the solving of algebraic problems, information is rearranged until the *unknown* is expressed explicitly through the *known* terms. Once this is accomplished, the problem ceases to exist. The problem in juggling is spatial distribution of objects and timing, or in other words a pattern with a certain rhythm. The solution is found by using the basic axioms, the *known*, by inventing a variation of the basic throws. Once the solution is found, the *unknown*, the problem of inconvenience ceases to exist. This analogy is completely described and documented in SOMMERS paper *Juggling as Performing Mathematics*[2]. In his paper he gives an overview of the striking similarities between teaching juggling patterns and teaching mathematics and he concludes, as the title suggests, that juggling is in fact nothing more or less than applied or performed mathematics.

Juggling & edutainment

Juggling develops not only mathematics insights. There are a great number of different positive aspects connected with juggling. Improving the motoric skills has a positive effect on the ability to write, read and reason. These effects have been researched intensively [6].

> *ñThe work of Dr. Carole E. Smith, Physical Education Specialist Lackland City Elementary School, 101 Dumont, San Antonio, TX 78251 Dr. Smith's work shows that learning to*

> *juggle can improve both handwriting and reading skills. Her research merely reinforces the work of Maria Montessori and Jean Piaget, both of whom hypothesized that gross motor movements and tactile sensation increased cognitive learning. If every student learns to juggle in primary grades, and they are constantly reinforced to improve their juggling skills, academic performance should improve accordingly.ò*

It is also a proven fact that taking juggling breaks during an academic task is advisable for everyone[7] ó*the activity is completely safe and non-disruptive. Juggling is like a "sorbet" for the mind, a "right brain break in a left brain day." It is low-impact aerobics that rhythmically and energetically exercises the big muscles close to the head and heart, pumping blood to the brain.*ô From my personal experience I can tell that this is certainly true and even while writing this paper I took a number of juggling breaks to improve my concentration. This proves that juggling can be seen as a educational tool and is not only entertaining. Those two features make juggling *edutaining*.

Conclusion

I hope that everyone who read this paper agrees that edutainment can cover a broad range of different disciplines and that there is a lot of edutainment hidden in all kinds of games and simulations. Iôm sure that there are many other examples of games with an almost imperceptible but valuable educational message although they are not generally labeled, sold, seen or even designed as edutainment.

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