The Curator's Take on the Wonderful CAPTCHA Exhibition

Nathan Zeldes, March 21, 2013

מוזיאון המדע ע"ש ברנרד בלומפילד ירושלים (ע.ר)
متحف العلوم على اسم بلومفيلد القدس
Bloomfield Science Museum Jerusalem

On Feb. 25, 2013, the CAPTCHA exhibition opened at the Bloomfield Science Museum in Jerusalem. Everyone was delighted: the dignitaries invited to the opening, the children who wasted no time to start exploring the exhibits, the adults who did the same at a more staid pace, the press, and of course the museum folks who had put in a huge effort to make it all a reality. We've pulled it off!

Which was far from trivial. When I accepted the role of curator for this exhibition over a year earlier I had no idea how challenging the task would be; nor did the museum. I'd built a number of exhibitions about the history of technology before, but none involved such deep conceptual difficulties, and none were so intellectually rewarding and edifying.

In this article I share the process we went through as we cracked the problems to come up with our exhibition, and I describe many of the exhibits we made, for the benefit of science educators.

The entrance to the exhibition

The challenge of the wooden blocks

It all began as a response to International Alan Turing Year in 2012. Israeli computer scientists were intent on honoring the founder of their discipline with educational activities, and the Bloomfield Science Museum made the decision to bring up an exhibition in this context. The exhibition's primary focus was to be Computer Science, not Turing himself; it was to introduce the scientific domain and tie it to Turing's work and legacy. Furthermore, our focus would be about the **Science** in CS, not about the much more familiar **Computer**. We decided to introduce the important concepts and problems that computer scientists work on, independent of specific computer models or technologies.

Oh, and by the way, ours is a hands-on style museum, targeting a population of school groups and families; in other words, we'd be making the science accessible to kids from age 8 up through adults. Which meant we'd have to make concepts like algorithms, the Turing Machine and RSA encryption accessible to elementary school kids, and preferably by using indestructible wooden blocks!

An exhibition in search of meaning

We pulled together a project team with representatives from the museum, academia, and design, and we spend a few months making lists and plans. We agreed on the key topics, or sections, of the exhibition, namely:

1. What is computation? (An introductory section, including algorithms).
2. Computability and its limits (including the Turing Machine concept).
3. Can computers think? (AI and the Turing Test).
4. Cryptography (Classical and modern methods, code breaking and Complexity).
5. How Computer Science is transforming our world.
6. Alan Turing's life and work (in a historical exhibit and in snippets across all other sections).

But we lacked one thing: a meaning, a unifying narrative, a story connecting all these areas into a coherent message. We actually went in circles for a long time, designing individual exhibits but trying in vain to figure out how to tie them into a coherent whole.

Disturbing questions

The meaning came in a flash. After months of immersion in the problems of CS and in Turing's work, a team member came to me and pronounced:

"I get what this exhibition is all about: it's that we look at the computer, and we see ourselves".

Bingo!

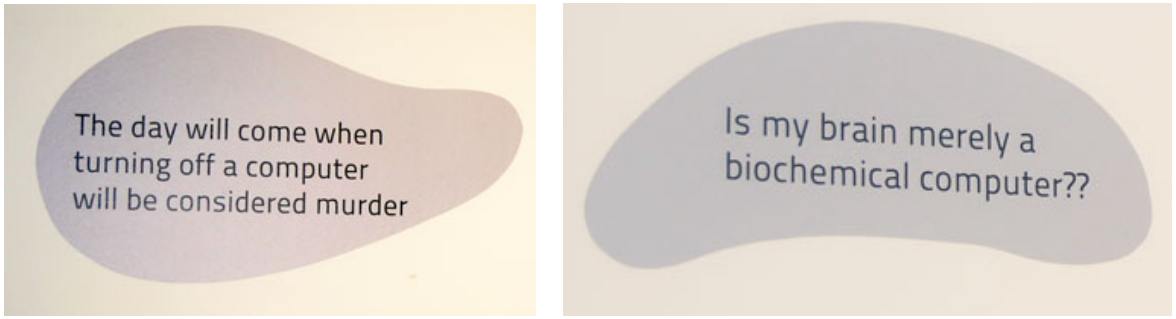
This succinct statement captured everything. Turing's major contribution, after all, was not cracking the Enigma, or even inventing the computer. His real breakthrough was realizing that the computer he was envisioning will be a parallel of the mind. He was only 24 when he formulated the Turing machine, but if you read his seminal article you see that he was doing that not by figuring how to build a computing mechanism (as Babbage had done a century earlier). Turing started from a "computer" – a human engaged in calculation – and had deconstructed the mental processes of this person to arrive at the abstraction that was to become the basis of every computer we use today. Then, after the war, he wrote "Computing machinery and intelligence", where he clarified his position that computing machines will one day become thinking entities just like us. (For more on my view of Turing's work see http://bit.ly/NZ-Turing).

And this leads to a plethora of fascinating, intriguing, and very disturbing questions, such as:

- Will computers ultimately develop true self-awareness?
- Is our brain merely a biochemical computer?
- Will killing a computer be considered murder one day?
- Can a computer be truly creative?
- Can a computer fall in love?

It is such questions, in my view, that make Computer Science – the subject of our exhibition – a key discipline at the bleeding edge of Science, alongside evolutionary biology, quantum physics, and cosmology. Absent the brain/computer duality CS would be a useful but philosophically indifferent trade, like aircraft design or refrigerator maintenance. It is the fact that we have what may or may not be a kind of computers in our skulls, and that CS has given us a new perspective on them, that makes this branch of science so fascinating. Alan Turing understood all this before a single computer was built, and the science he founded is permeated with these questions.

As is the CAPTCHA exhibition: many of these "disturbing questions" are stenciled on its walls, and are implicit in its exhibits. We hope that the older kids and the adults will remember some of them after they leave.



"Disturbing questions" on the walls of the exhibition area

The very name we chose, CAPTCHA (those twisted word images used by web sites to distinguish humans from web bots in an inverse Turing Test) expresses the brain/computer duality and the link to Turing; and the exhibition's logo captures the reflexivity of these two entities as they ponder each other.

Exhibition logo

Designing a fantasy wonderland

The design of the exhibition space was entrusted to Chanan De Lange, one of Israel's leading designers. Chanan's design concept was a far cry from what you (or I, for that matter) would expect from an exhibition devoted to a technological subject. It transformed the space into a fantastic, almost whimsical swirl of fluid shapes and curved patches of color. Even the floor was to be a composition of multicolored PVC patches, and the tables and benches didn't have a single straight line between them.

It was hard to see where this would end from the CAD drawings, but when the last roll of PVC was painstakingly cut up and glued in, we could see the beauty of it all. The absence of the usual ultra-modern “technology” theme enhances the focus on the abstract concepts of computer science, embedded as they are in a colorful playground, separately from the specific technology of our day; the predominantly orange furnishings deliver a warm and delightful atmosphere; the many intriguing exhibits add to the fascination. As one adult visitor put it, the whole thing is simply inviting.

Two snapshots conveying the exhibition’s look and feel

Another snapshot showing the exhibition's look and feel

The effect is enhanced by the "collages", five murals that capture the essence of each of the main topics in a fanciful visual play on the computer/human duality.

Mural: The computer is not omnipotent

Mural :How computer science is changing our world

A potpourri of wondrous exhibits

I won't give a list of every exhibit, but I will describe many of them to give you a taste of the experience they give our visitors – and of our objectives and dilemmas in designing them.

Exhibition entrance

As they approach, visitors are confronted with a double gate, bearing the inscription "Computers will never learn to love", and arrows directing the visitor to use the right or left entrance based on whether they agree with this. Once through, they see a screen with the tally of supporters and

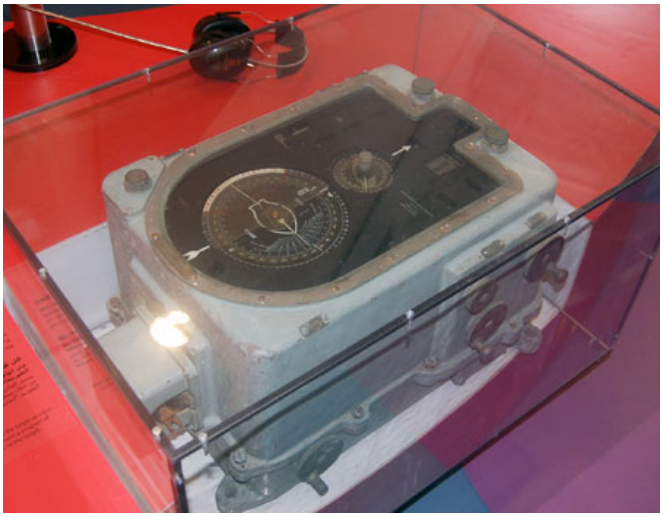
dissenters, with their own action incrementing the count. Of course this is hardly an accurate scientific survey, but it does make one think...

"Voting gate" at exhibition entrance

Section 1: What is computation?

In this section we focus on two takeaways: that a "computer" need not be the electronic device usually called by that name, and that the concept of the *algorithm* is at the heart of computation.

The diversity of what a computer can be (or not) is illustrated by a set of nine objects dispersed throughout the exhibition in their own small showcases, each with a caption "*Is this a computer?*" and a brief answer. We have here an analog planimeter, a calculating lightmeter, a washing machine (with a transparent case showing its internal controller), a car's ABS computer, a digital hearing aid, a notebook computer, a mechanical Torpedo Data Computer from a WWII submarine, a manual meat grinder – and, of course, a lifelike model of the brain!

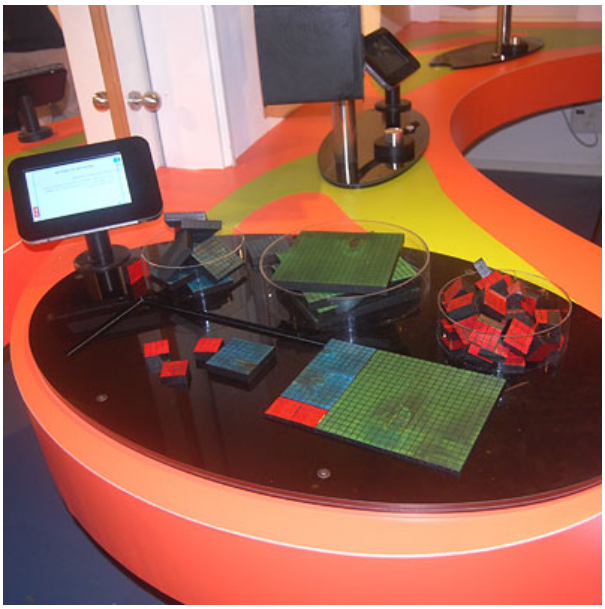


Two "Is this a computer?" exhibits: a WWII Torpedo Data Computer and a meat grinder (which has an input and processes it to an output, but lacks a program and is therefore not a computer).

The concept of an algorithm is demonstrated through three interactive exhibits:

- **Maze solving algorithms.** Two touch screens embedded in the counter top present mazes, which visitors can trace with their fingers (leaving a colored trace on the screen). They can then see how the computer would solve the same maze using two algorithms (BFS and DFS).

Maze solving algorithm



Euclid's algorithm

- **Euclid's algorithm.** We realized this ancient method for computing the greatest common divisor of two integers not with sticks but with square plates that are used to tile a rectangular frame, like pieces in a toddler's puzzle. Remember the wooden blocks requirement?...

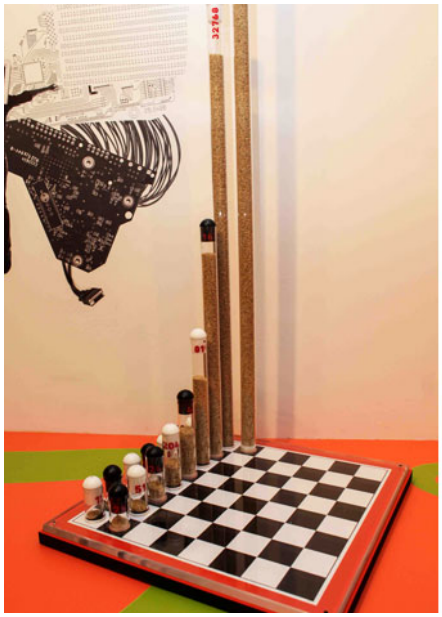
Compute a Pizza! Exhibit. The recipe is entered on the five large wheels.

- **Compute a Pizza!** This takes to extreme the common analogy between an algorithm and a cooking recipe. The visitor can define a Pizza, by setting four large wheels, one for each layer of the pizza – for instance, the first layer may consist of dough, biscuits, plasticine, or mud; the second of cheese, tomato sauce, marshmallows, olives, or sand; and so on. A fifth wheel defines the cooking process – various baking times, roasting, frying, etc. Once the recipe is specified on the wheels, the visitor hits a large red button and the pizza defined is created by an amusing actor on a video screen, resulting in a product that may or may not be edible.

Section 2: Computability and its limits

The existence of limits on what is computable plays a key role both in Turing's thought and in modern cryptography, and we had to find a way to introduce this to our audience without getting too technical. In this section we introduce some underlying concepts, using (among others) the following exhibits:

- **Tiling the plane.** We present the visitor with a row of tiling puzzles of increasing complexity, including three unsolvable one, using chessboard and Wang tile problems. The idea is to show that some problems have no solution while others require increasing time to solve.
- **Exponential runaway.** This is made tangible with the classic "rice grains on the chessboard" tale, implemented as columns filled with rice that get longer and longer until the last one actually punches through a hole in the ceiling!



Exponential runaway

Tiling problems

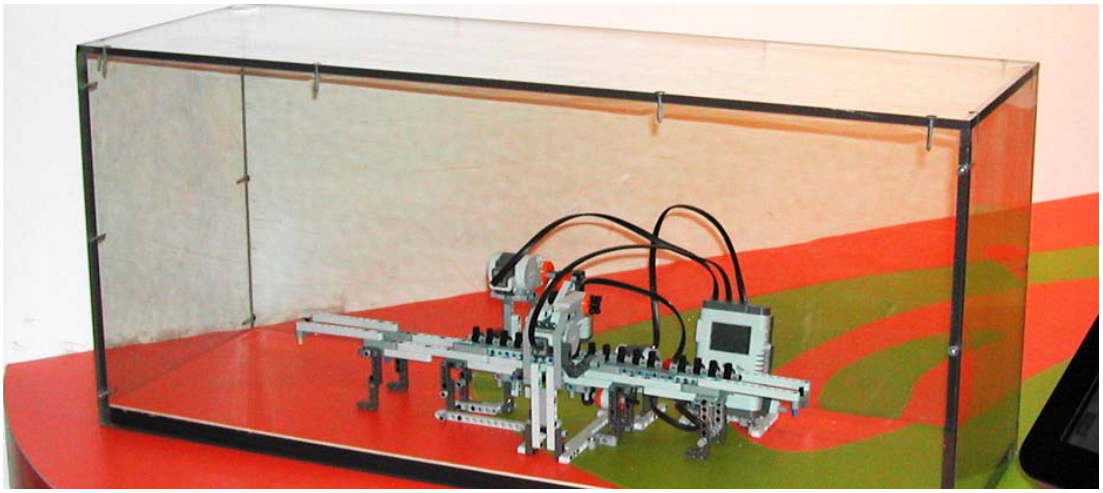
- **Impractically long time.** We challenge the visitor with a one dimensional jigsaw puzzle where the correct order is from very short to very long time scales. Puzzle pieces bear times from the fleeting Planck Time to the age of the universe, including the times to crack passwords of various lengths by brute force, and the time to factor large numbers. Solving the puzzle forces one to grasp the magnitude of the computing tasks along the continuum of short and long time scales.

We present the Turing machine in two exhibits:

- **A unique two-dimensional Turing machine** developed with the help of Prof. Nachum Dershowitz of Tel Aviv university. This machine uses a two dimensional "tape" of squares that can be manually changed between white and blue states, and has a manually movable head – a disk marking the current square. The visitors are asked to operate the machine themselves, by moving the head and modifying the squares in accordance with a flow diagram which implements the machine's instructions table. The three exhibited machines allow executing functions of AND, XOR and SORT.

Three two-dimensional Turing machines

- **A Turing machine implemented in Lego Mindstorms.** This is reproduced, with permission, from the one built by CWI in the Netherlands. It is fully functional, but its fragility precludes letting it run continuously. Instead, it is protected "under glass" and is demonstrated from time to time by a museum guide.



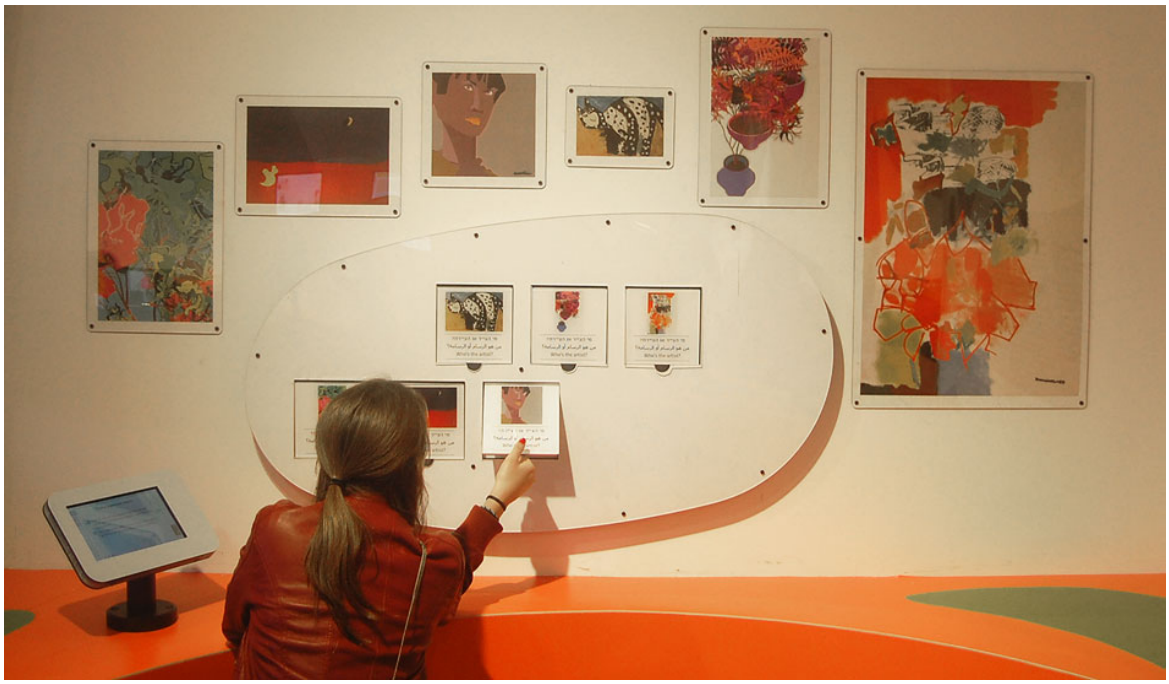
Turing machine realized in Lego Mindstorms

Section 3: Can computers think?

Until a computer can pass a general Turing test (if it ever will) we made do with tests within two limited domains from the art world: painting and music.

Left to right: Tic Tac Toe player, Computer painter, Computer composer.

- **The computer painter** exhibit shows six paintings, three by human painters and three made by the program AARON developed by artist Harold Cohen. People are asked to decide which are which, and can check themselves by lifting small panels that hide the correct answers.



Computer painter exhibit. The visitor is lifting a panel to find who painted the face picture.

- **The computer composer** exhibit plays classical music in three headsets: two pieces by human composers and one created by the IAMUS computer developed at the university of Malaga. People are invited to listen and decide which is the computer's creation, and can then check their answer by uncovering panels that show the true attribution.

Other exhibits in this section are:

- **A Tic Tac Toe program** that visitors can try to defeat. The program shows in real time its thinking process – the rules the algorithm follows to test the board position – and the visitor can remove one rule at a time to see the effect on the machine's "intelligence".
- **An adaptation of the classic ELIZA** psychotherapist chatbot, which is able to chat in both Hebrew and English.
- **A specially developed Hebrew implementation of reCAPTCHA**, the method used by Google Books to allow humans to help identify words in scanned books. The Hebrew version is linked to the Israel National Library's ongoing effort to scan and digitize old Hebrew books and publications; visitors are shown pages from such books with ambiguously identified words highlighted, and the visitor can type in the correct word which – if corroborated by a number of visitors – is added to the library's database. For once, it is human brains that help out the computer!

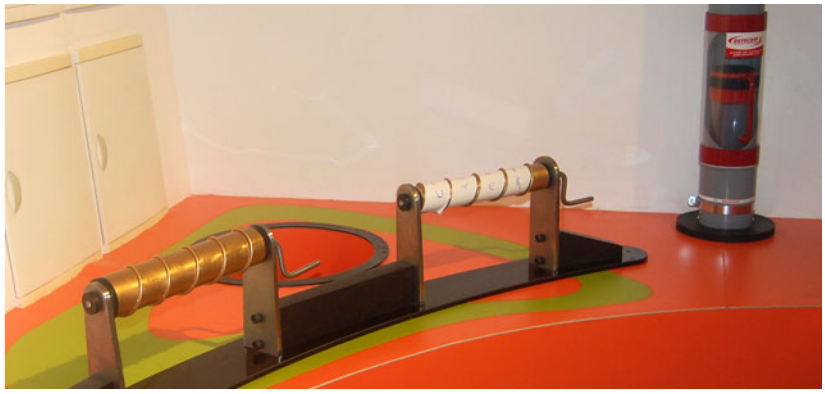
Section 4: Cryptography

Cryptography has two faces: before computers it was practically child's play, all about shuffling letters and guesswork; once computers arrived it became an intensely mathematical discipline. In CAPTCHA we deal primarily with the former kind; we reluctantly gave up on a full exposition of RSA and public key cryptography, but we did hint at the direction they take by showing the factoring problem. And then there's the Enigma!...

Exhibits in this section:

- **Cipher wheels.** This classic device is implemented as a large stationary alphabet wheel with interchangeable moving wheels that implement Caesar, Atbash and an arbitrary substitution code. Visitors are given coding forms where they can write, encrypt or decrypt messages.
- **The Scytale.** The ancient Greek method of writing lengthwise on a strip wrapped around a rod. We have three of these rods, with different diameters; decryption requires finding the correct diameter.

Cipher wheel



Two Scytales, with the pneumatic mail load station at the right

- **Pneumatic mail.** We built two identical stations at opposite ends of a hall, each with the cipher wheels and the scytales, and connected them with a pneumatic mail system. The idea is that visitors can encrypt a message at one end, put it into a canister and send it careening in the transparent mail tube that winds twice (for added effect) around the ceiling to the opposite station, where another visitor can decrypt it. Great fun all around!

Two cryptography stations (back of hall, right and left) connected by the pneumatic mail tube above

- **Frequency analysis.** This is an interactive computer station that presents the visitor with an encrypted message in the language of their choice, and presents the letter frequency distribution of the message and of the language; the user can guess at letter substitutions and gradually build the plaintext message.
- **The Enigma!** We exhibit a genuine German Enigma machine, which elicits much excitement from our adult visitors.

Enigma cipher machine

- **Factoring large numbers.** We introduce the concept of asymmetric or trapdoor problems in an exhibit where visitors are asked first to multiply numbers of increasing length, and then to decompose numbers into their factors. The asymmetry in the difficulty of these inverse tasks becomes very obvious. In the accompanying explanation we discuss the significance this has for modern cryptographic methods such as RSA.

Section 5: How Computer Science is transforming our world

In this section we wanted to convey the relevance of all this seemingly arcane science to one's daily existence, and also to show the significant contribution of Israeli scientists in the field, in the hope of encouraging young visitors to consider a career in Computer Science.

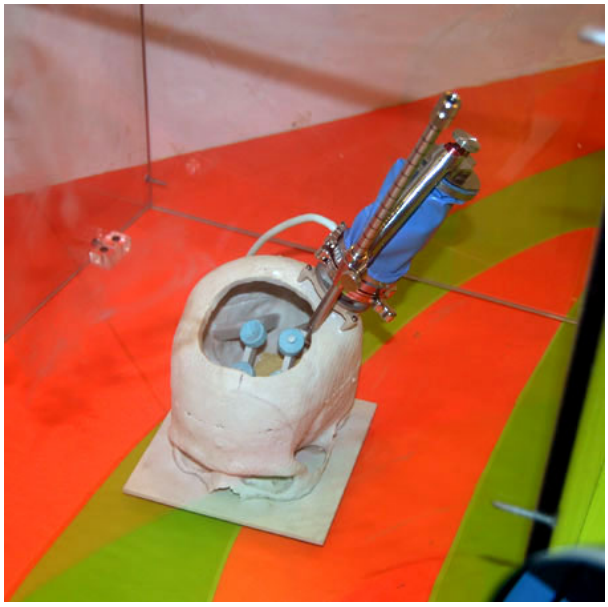
We have six exhibits titled "Doing X differently", with X being some field of familiar activity:

- **Healing differently** – a model of the brain surgery robot from Mazor Robotics, and a video showing it in use.
- **Researching differently** – a video of a simulated galactic collision.
- **Proving differently** – an interactive map coloring application based on the 4-color theorem, which was proved using a computer.
- **Touring differently** – an interactive computerized exhibit allowing the visitor to select a location and be "taken there" using a combination of Google street view, satellite view and weather data.
- **Driving Differently** – a Mobileye driving safety simulator.
- **Communicating differently** – "Plant a comment", an art installation by the artist couple Omer and Tal Golan, demonstrates the 'wisdom of the crowds' revolution. Visitors can text (SMS) their comments to a given number and the text is added as "branches" to "concept trees" in a virtual landscape shown on three large screens, and navigable with a 3D mouse.

"Plant a comment" art installation

Leading Israeli computer scientists are showcased on a "wall of fame", with a nearby screen running a video interview with four of them, where they describe their motivation, research highlights, and their thoughts about Turing's influence.

Leading computer scientists wall of fame



Mazor Robotics brain surgery robot

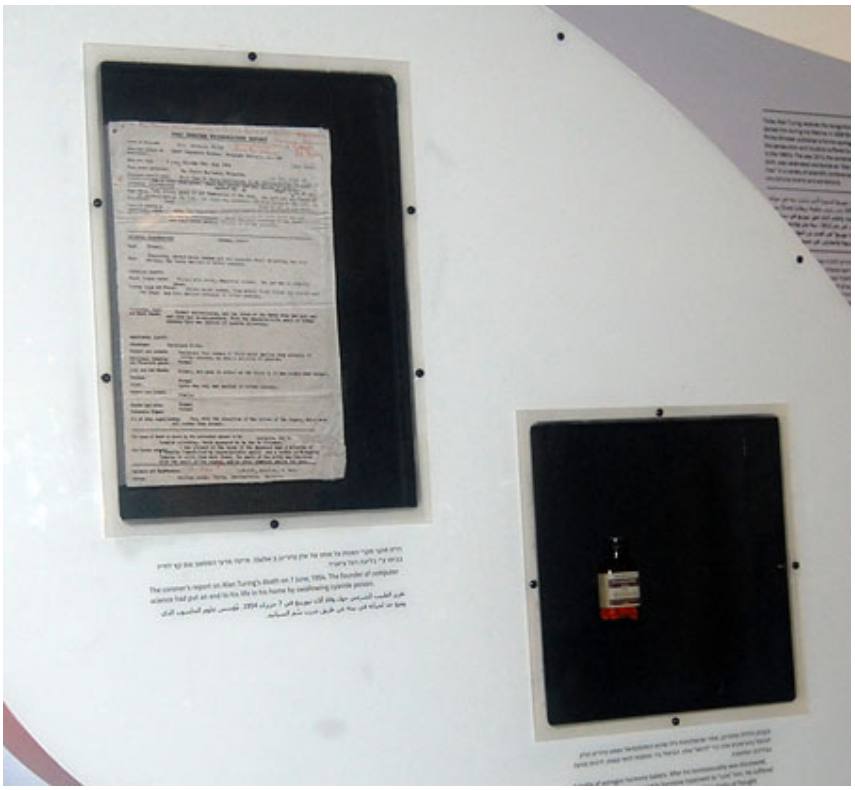
Section 6: Alan Turing's life and work

Turing's tragically short life and huge contribution to science are presented in a static exhibit at the entrance to the exhibition.

Alan Turing's life and work exhibit. The screen shows images from Bletchley Park.

In addition to descriptive text and photographs covering Turing's life and activity, we have the following items (or their facsimiles) on display:

- Reprints of Turing's two world-changing papers, "On computable numbers" and "Computing machinery and intelligence".
- A looping slideshow about Bletchley Park, contrasting photographs from the war years with current restorations of the same buildings and computing machines.
- A bottle of Stilboestrol pills (the Estrogen hormone "therapy" forced on Turing).
- The coroner's report regarding Turing's death by Cyanide poisoning (this, and the pill bottle, are a recreation – with permission – of exhibits in the Codebreaker exhibition in the Science Museum in London which I found to be very effective on adult viewers).
- The recent apology of British PM Gordon Brown.
- The first day cover of the Royal Mail's Turing stamp.



Coroner's report and the bottle of Estrogen pills, in dark recessed showcases

In addition, those exhibits throughout the exhibition that are directly related to Turing's work are marked by a small photograph of his face accompanied by an explanatory text.

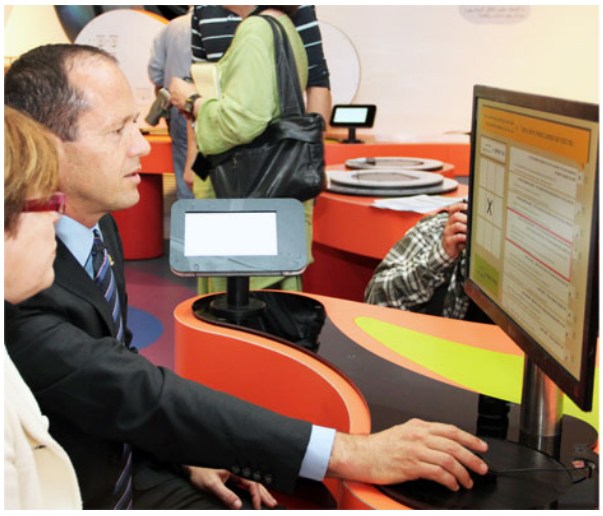
Pulling it all together

Building CAPTCHA was a complicated process. In addition to the difficulty of defining the exhibits, we had to secure a diverse range of objects – none more hard-to-get than the Enigma, admittedly. Other items were bought on eBay, while yet others were secured from archives in the UK. Most exhibits were designed and constructed in the museum workshop, and while most worked as planned, a few required revision to attain reliability in the face of children's insatiable curiosity and destructive vigor...

A design decision that had made our lives "interesting" was to use tablet computers for all the captions, explanations and instructions. This was the first time the museum had made such a move from ink to pixels. Each exhibit has an accompanying tablet, and each tablet has three screens – operating instructions for the exhibit on the "Home" screen and two screens of further explanations. Multiply this by three (for Hebrew, Arabic and English versions of all the content)...

The launch was accompanied by a special art exhibition called "Other Lives", curated by Maayan Sheleff, in which Israeli artists were invited to exhibit works inspired by Turing's work and legacy.

CAPTCHA will remain open in Jerusalem for about three years, and you are welcome to come and enjoy it – as did these two of our first visitors, on opening night:



The mayor of Jerusalem, Nir Barkat, pitting his skills against a Tic Tac Toe algorithm – while one of his younger constituents is having a great time with the blocks that illustrate Euclid's algorithm.

Acknowledgments

This exhibition was made possible by the wonderful collaboration of many different people, from museum staff to freelance professionals to college students. I was heartened by the spirit of real cooperation and goodwill that made working with this team an intense pleasure. Here they are:

Curation and development
Nathan Zeldes

Scientific consultation and development
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Varda Gur Ben Shitrit

Exhibits development
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Interactive design
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Tablets script
Ram Almog, Red-id

Animation
Tami Sivan

Software development
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Production management
Uri Sinai

Construction & Production
The workshop Team of the Bloomfield Science Museum Jerusalem

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Nathan Zeldes is a physicist, hi-tech veteran and globally recognized expert on knowledge worker productivity, of which he blogs at http://www.nathanzeldes.com. For his collection of historical computing artifacts, see http://bit.ly/NZ-Hobbies.