How to Tell a Human apart from a Computer

The Turing Test

(and Computer Literacy)

Are Computers like Human Brains?

- The impressive contributions of computers during World War II made them earn the eponym of *Giant Brains*.
- There is a superficial similarity between the switching circuits that made up computers and the cells of the human (and animal) nervous system.

A Superficial Similarity - 1

- The nervous system (including the brain) consists of cells, neurons, that have an elongated part (axon) and connect to other neurons through structures called **synapses**.
- Under certain conditions a neuron becomes "excited" transmitting an electric wave called *action potential*. When displayed on an oscilloscope the wave has the form of a spike that has a fixed size for a given preparation.

A Superficial Similarity - 2

- The fact that a neuron can have only one of two states (quiet or transmitting a spike of fixed size) seemed to make neurons similar to the switching circuits of a computer that can be ON or OFF.

First Fallacy

- While the spike of the action potential has a fixed amplitude a neuron may fire several of them and the time between spikes seems to be an important carrier of information. Therefore neurons are not binary devices.

Second Fallacy

- There are billions of neurons in the human brain and their connectivity is the result of millions of years of evolution. In order to build a computer able to simulate the human brain it is not enough to start with basic blocks that may be similar in the two systems. We have to figure out how they are interconnected.

A Sobering Truth

- Being successful in programming machines to solve mathematical problems tells us nothing about the prospect of replicating human intelligence.
- Mathematics is a human invention that came very late in our evolutionary history so our brains are not well adapted to mathematical tasks.
- It is quite a different story with tasks such as recognizing faces and facial expressions.

What the Pioneers Said - 1

- John von Neumann wrote a short monograph, *The Computer and the Brain*. He wrote it in the hospital while fighting the cancer that eventually took his life. In the book "he observed that the basic computing hardware of the brain indicated a different methodology than the one used in developing the computer".

What the Pioneers Said - 2

- Turing proposed a test to determine whether a machine exhibits human level intelligence.
- A person sits on a teletype and types questions that are sent to someone in another room who then replies.
- The questioner tries to determine whether the responder is a human or a computer. If it is a computer and the questioner thinks the responder is a human, then the computer passes the Turing test.
- No machine has ever passed the Turing test.

A Modern Application of the Turing Test

Completely
Automated
Public
Turing test to tell
Computers and
Humans
Apart

or CAPTCHA

CAPTCHA

- **C**ompletely
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  Humans
  Apart

SOME CAPTCHA RESOURCES

http://www.captcha.net/

http://caca.zoy.org/wiki/PWNtcha

http://www.cse.lehigh.edu/~baird/research_hips.html

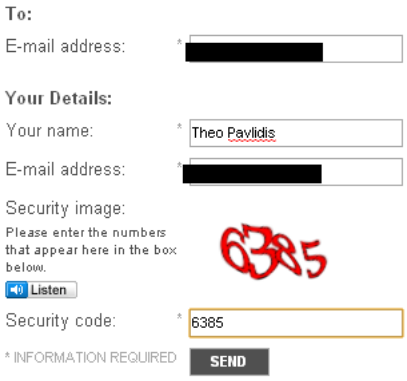
Some History

- CAPTCHA was the invention of Luis von Ahn and his doctoral advisor Manuel Blum at Carnegie Mellon University (2000-2005).
- Von Ahn grew up in Guatemala City and in 2011 the *Foreign Policy Magazine* (in Spanish) named him the most influential intellectual of Latin America and Spain.
- Von Ahn also pioneered the concept of crowd-sourcing.

CAPTCHA - 1

- Many web services want to make sure that user accounts are set up only for people and not for computers. (Computer programs that visit web sites are called web-bots, a contraction of web robot.)
- How can they tell apart a web-bot from a human?
- By asking the prospective user to pass a Turing test! If the user passes the test, the web service assumes that the user is human, otherwise the service rejects the user as a web-bot.

CAPTCHA - 2



Another Name for the test **HIP**

- **H**uman
  Interaction
  Proof

THE SEMANTIC GAP

- CAPTCHA/HIP relies on the semantic gap.
- Computers deal directly with numbers or letters that have a simple numerical code but everything else, **Speech, Music, Pictures**, must be converted into numbers.
- The numerical representations may not capture the semantics of the original.

Dealing with Pictures- 1

- When a picture is taken with a digital camera, it is subdivided into tiny areas and information about their color is stored in the camera memory and, eventually, in the computer memory.
- These tiny elements are the **pixels (picture elements)**. Because any color can be expressed as a combination of red, green, and blue, for each pixel we store the values of these three colors.

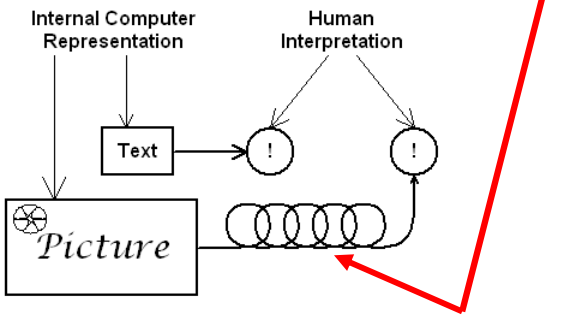
Dealing with Pictures - 2

- The characters in a text are natural elements and they describe the text whether stored in computer memory or chiseled in a stone tablet.
- If you know how to read, the sequence **fox** conveys the concept of an animal with, usually, brown fur and a long tail.
- Characters are mapped into numbers that are easily processed by a computer.

Dealing with Pictures - 3

- The trouble is that pixels have no meaning for humans. One must create from them other entities that capture properties of a picture that are meaningful to people and that is not an easy task.

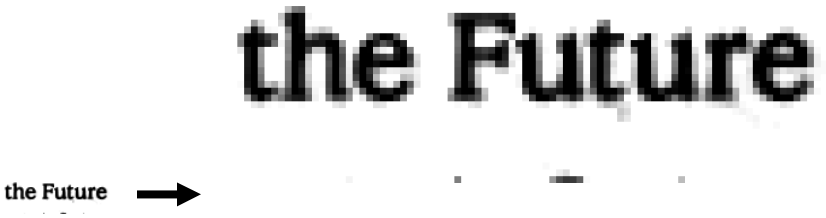
The Semantic Gap Illustrated



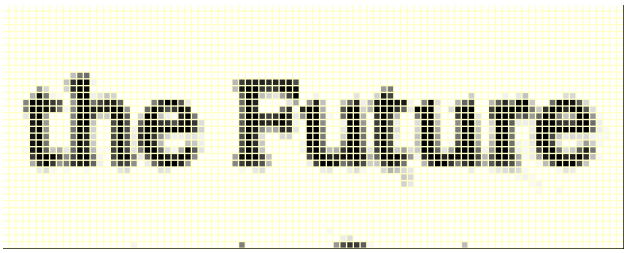
How Computers Read
Optical Character Recognition (OCR)

- Step 1: Separate print (usually dark) from background (usually light).
- Step 2: Pick up individual characters (group of dark pixels)
- Step 3: Identify their shape by looking for strokes, loops, corners, etc
- Step 4: Use rules to classify. For example, an H has two vertical strokes and a short horizontal strokes.

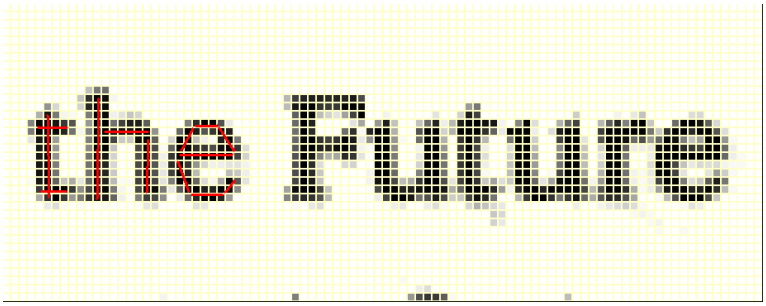
Pixels of a Text Scan



the Future →

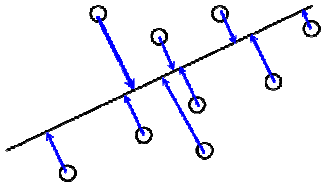


Making Sense of the Pixels in the case of Text



To reach an anthropomorphic description of the image we need to fit lines along groups of dark pixels. (Other representations are also possible.)

Digression: Fitting straight lines into pixels (or other points)



For a given line find the distances of all the points from it (blue line segments). Select a line that minimizes either the maximum or the average distance.

Frustrating OCR

1	Separate background from print	Use messy background.
2	Pick up individual characters	Have them blend with each other.
3	Find strokes, loops, etc	Make the letters “wiggly”
4	Apply classification rules	It should be hopeless by this point.

Status of OCR

- In spite of over 60 years of research the problem is not completely solved.
- Google uses OCR to create electronic versions of books and their machines have recognition rates no better than 98%.
- But that is enough for Information Retrieval!
- Advances in OCR may eventually defeat text CAPTCHA!

Challenges for CAPTCHA

From an e-mail from Microsoft Research

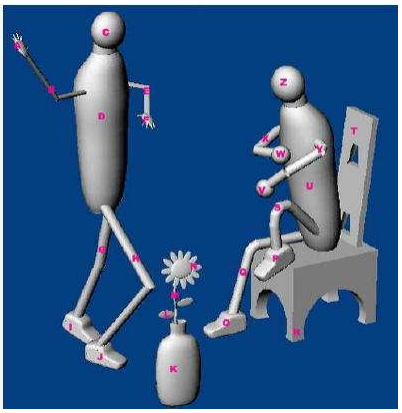
1. How easy is it to generate? For hotmail, we need to generate in the order of 1M new different challenges per day. It may seem like a good idea for a HIP to present a picture of a cat or a dog and ask which one it is, but it is completely impractical to obtain 1M different pictures per day Where do we get these images? How do we label them reliably? How do we make sure that no offensive images sneak in? What is the cost of storing them? What is the bandwidth cost? Etc. Character based HIP systems can generate hundreds of new unique HIPs per seconds on one machine.

Challenges for CAPTCHA

From an e-mail from Microsoft Research

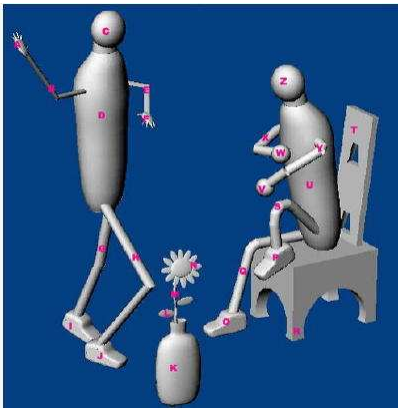
2. The HIP must be resistant to brute force attack. Human can label a HIP at a cost of 1-3 cent per HIP. A computer that does intense visual processing and succeed 1 in 10,000 has about the same cost. An algorithm that lets the computer succeed 1 in 100, reduces the cost to 100 time less, meaning that the HIP is broken.
3. The HIP must have a very small cognitive load on the human, otherwise users hate it and just do not use the service.

A 3-D CAPTCHA developed by **Michael Kaplan**



Have a graphic display model for a scene and display a different view each asking the user questions about the scene.

A 3-D CAPTCHA developed by **Michael Kaplan**



Please click on or enter each letter corresponding to the following list in the field below. You must enter them in the exact sequence listed.

- The Head of the Walking Man
- The Vase

User^8mq _ _ @DOMAIN.COM

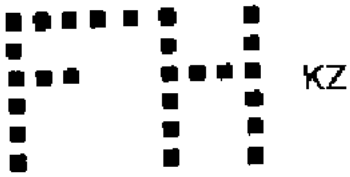
In this case the user must type **C** and **K**.

The Importance of Context

- "Human intelligence almost always thrives on context while computers work on abstract numbers alone. … Independence from context is in fact a great strength of mathematics."
- Source: Arno Penzias *Ideas and Information*, Norton, 1989, p. 49.

What Do You See?

Reading Demo – 1



It is hard to explain the human ability of reading dot-matrix print and fine laser print by just examining pixels.

Reading Demo - 2

Reading Demo - 2

Tentative binding on the letter shapes (pixel based) is finalized once a word is recognized (meaning). Word shape and meaning over-ride early cues.

Reading Demo -3

New York State lacks proper facilities for the mentally Ill.

The New York Jets won Superbowl III.

- **Human readers may ignore entirely the shape of individual letters if they can infer the meaning through context.**

More Challenges for Computer Reading

- Mathematical tools are a poor substitute for knowledge of human perception.

Which one of these three shapes does not belong with the other two?