Stage 1 Capstone Paper

THE ESSENCE OF COMPUTER SCIENCE IS…

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Computer Science in Practice

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From the studying of this course, Computer Science in Practice, we can deduce our unique personal answer to the question “What is the Essence of Computer Science?” My perspective is that computer science thrives on improving society, and to do so, it must first understand and communicate with society. This can be done by understanding the trends of language, by using Zipf’s Law, power law graphs, Google Ngrams and Data Analytics. To improve society communication is key, which has been done with compression and speech technologies. Lastly, we can combine all of these data to improve human-computer interaction and design robots. To ultimately progress the evolution of humanity into the improved technological future.

The idea of studying human language mathematically is not a recent idea. Zipf’s Law created in 1930 studied the power law curve which occurred when the frequency of words in Moby Dick was counted and graphed. To represent that “only a few words are used very often, many or most are rarely used.”. This ideology which is similar to Pareto 80/20 principle, can be used to spot common words and phrases used in certain articles, or conversations. For example, Prof. Mark Keane’s article Mining the Web for the “Voice of the Herd” to Track Stock Market Bubble. They studied the power-law distribution of the word count of 17,713 online finance articles from the Financial Times, the New York Times, and the BBC. This was used to predict stock market bubbles. The model was based on Zipf’s theory, which language tends t follow the power-law with the equation $y = \mathrm{C}x^{-\alpha}$ $\mathrm{C} = e^{\mathrm{c}}$

They noticed and hypothesised that during a bubble the language of the articles would “Verb-convergence” The variety of verbs used became smaller, and they were all uniformly positive, e.g. “scaled new heights.” Also they “noun-convergence” the articles focused on a few big market companies (including the dot.com websites, which had a rapidly rising stocks. Their method to come to this hypothesis was that they searched the BBC, NYT and FT for all articles on the major stock indices, Dow Jones, FTSE 100, and NIKKEI 225. Which resulted in 10,418,266 words over four years. They use Sketch Engine to highlight and collect specific words and used lemma to include all the different variations of each word, e.g. fall, fell, falls. They noticed that before the bubble pop before 2009 the words that were frequently used were the positive, rise, gain. While afterwards the words turned negative, e.g. drop, lose. The bubbling of a country’s economy can dramatically affect lives and be able to predict that can drastically help society, and help protect the economy.

While this method expresses the uses of statical evidence can be used to predict humanity, the use of Ngrams can understand the trends in the past. Ngram uses grammatical analysis to break down sentences into useful and consecutive pairs of words. This method is then used to count the frequency of words and collections of words in books. Thus from this, we can detect trends, and compute the co-occurrence of one word with another.

Unigrams can be used to deduce the first and frequency of mentionings of particular words. Bigrams allow us to understand the popularity of people or ideas, due to the use of grouping two words together. While lastly, Trigram describes the popularity of phrases and the first instances. These graphs can be used to analyse and record trends, events and pop culture throughout history through the use of books. With the studying of popular trends, we can see a common graph form, which has been called the Bass Diffusion Model.(Figure 1) From programs can be created to analyse the frequency of words on the internet/books and be able to predict new trends. This data can help us understand how popular ideas are formed, and possibly could be used by business for marketing efforts. The need for computer scientists to understand language and society it the reason why I think the essence of computer science is to improve society.

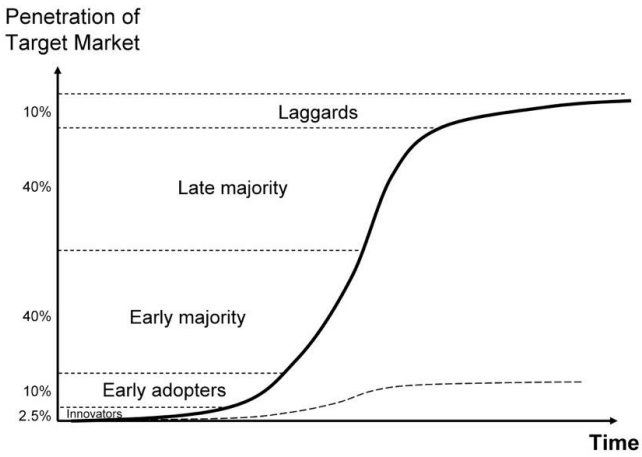


Figure 1: Lecture 7 Text Analysis Slides

With the use of data collected about language, to further improve society, computers have to be able to understand human speech. Which is why speech technologies are important. There can be a variance between the different automatic speech recognition software. However, they usually follow the same criteria. They either have a small vocabulary, which is popular in simple common orientated software, such as the Microsoft Xbox Kinetic recognising particular terms, such as “Xbox” or “play”. Or they have a large vocabularies database which hundreds of words for a variety of tasks, such as the Amazon Echo. They also can be either discrete or have continuous recognition, the first method requires pauses between words, while the latter the speaker can talk freely. From these two criteria, is it obvious which is the better system, which is why a majority of software has a large vocabulary with continuous speech recognition.

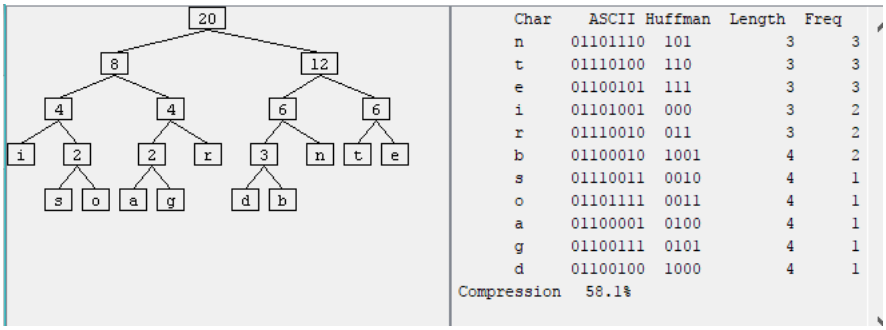
Some other criteria are speaker dependent versus independent, speaker-dependent is personalised to the user, and the user has to train the software, while the independent requires no training. However, with the variances in accents and dialects, the independent software can have problems distinguishing the correct phrases due to national inflexions. Once the speech is recognised as text, it has to be split into sentences, some software such as the Linguatec tools identifies sentences boundaries. This is done by understanding rules of punctuations, and start-of-sentences and end-of-sentence words, for example, “the” would more likely be a sentence stater, and it wouldn’t be grammatically correct to have “the” at the end of a sentence. Also, it has to know the different types of abbreviations, such as “Prof.”, or “etc.”.

Speech to text recognition improves the interaction between human and computers and allows for systems such as Google, to be more easily accessible to visually impaired, or simply allow humans to do computer needed tasks on the move, or allowing tasked to be performed without the need for physical input like a button click. However, to improve accessibility, there is a need for text to speech software, which allows for people who are visually impaired to use electronic devices. Also, it allows for a conversation between humans and computers. This ‘Speech Synthesis’ can be done with a letter to sound system. It takes the text and splits up each word and letter and identifies the audio counterpart. This counterpart is found with the use of speech databases and speech models, such as pronunciations, duration and pitch. These single audio files are combined to create ‘speech’. However, this system can have trouble with words which have the same spelling but are pronounced differently. For example tear, as in a droplet of water, or a rip in a piece of fabric. To solve this issue the software needs to be able to understand the context of the sentence and understand which pronunciation is grammatically correct in each situation. The software also needs to be able to recognise aberrations such as Dr. as ‘doctor’ and to be able to see September 1st and possibly instead say first of Septemeber. This knowledge will create a more natural speech pattern for the software and improved the connection between human and computer. This connection can allow us to use computer and machines easily and efficiently, and thus improve human growth.

Another method for improving efficiency it the compression of data, this allows the sharing of data to be done faster and therefore the sharing of information has become much more accessible. Claude Shannon

theorises that every message is made up of Information and Redundancy. Redundancy is the filler, non-shortened words. His modern communication theory created in the 1940's has applications in compression. When text message chargers were per a byte, it was expensive to use full sentences. Therefore message shorthand was formed, this was a method of compression. The sentences aren't grammatically correct, but the information is still kept, which makes it more efficient. A computerisation version of this is the use of coding and decoding, which is compressed as possible. A method of coding is called Prefix Code, which describes a method of assigning a letter a codeword which has no prefix, no codeword is a prefix of another code word. This makes the encoded messages are uniquely decodable, and creates a binary tree.

Prefix code can be used alongside Huffman coding which uses the most frequent letters in the higher area of the tree, while less frequent are lower. Vowels would be more frequent thus, 'a' could be 00, while 'z' would be 000001. This lowers the overall average size of messages. To do this you combine the two least frequent nodes, and this creates a branch, repeat this until you have your tree. (Figure 2) With compression, however, this is a possibility of ideas or information being lost for the sake of efficiency. Due to this the term 'Lossless' and 'Lossy Compression' was formed. Huffman code is an example of lossless compression; the original message can always be achieved exactly during decode stage. While MP3's however, are considered lossy compression due to the original message can never be obtained once it has been compressed. MP3's removes frequencies which humans can't hear from the audio file; it also uses inexact approximations and partial data to discard information, which reduces the file size to around an average factor of 10. The CD is very similar to an uncompressed audio, which means it more like the lossless compression. The MP3, when compared to the CD, reduces the size by 75 – 95%, thus making it more viable and popular for internet storage of audio.



Char	ASCII	Huffman	Length	Freq
n	01101110	101	3	3
t	01110100	110	3	3
e	01100101	111	3	3
i	01101001	000	3	2
r	01110010	011	3	2
b	01100010	1001	4	2
s	01110011	0010	4	1
o	01101111	0011	4	1
a	01100001	0100	4	1
g	01100111	0101	4	1
d	01100100	1000	4	1

Compression 58.1%

Figure 2: Huffman Coding example

Compression has allowed massive amounts of data to be stored and is possibly the main component in the rise and creation of the internet. Compression allows for information to be sent easily and efficiently to any location in the world. This has allowed the vast population to have access to information outside of the environmental circle, which creates a more connected society. The sharing of information can greatly improve science and the creation of ideas. This therefore greatly improves humanity and is another reason why I personally think that the essence of computer science is to improve society.

Another way computer science improve society is by the use of robots. Robots are a physically-embodied, artificially intelligent device with sensing and actuation. They use sensors and processors to think and take action, and they required a high cognitive ability. Robots can efficiently and more safely do task compared to humans. For example, Robot arms, which are the most commonly used robot, are essential to modern factories, due to them being able to precisely carry out tasks. They also have a lesser risk of damaging or contaminating the product and can handle objects which wouldn't be safe for humans to touch. Therefore robots have improved production, which allows humanity to design, create and produce products more efficiently and quickly. However for this robot arm to work, they either need to have the surrounding information internally placed in its memory or for it to have sensors to 'see' its environment.

Proprioceptive sensing which senses the robots internal state, this is done by Whell odometry, tilt sensors, gyros, compass and internal force sensors. They also externally sense for the environment surrounding the

robot. This can be done by sensing at a distance, with soundwaves, infra-red laser or visual lighter, or they actively sense with sonar, laser range-finder, which sends and receives data. Or Passive sensing by the use of camera or microphone which receives ambient signals. For robots to be mobile, this also needs actuation for locomotions and sensors for guidance. For example, Google cars have path planning, mapping, navigation and plentifully internal processing and sensors. SLAM most famous for map planning and for navigating a space, it can calculate the quickest path from a to b.

Whereas is it a great improvement to have robots and computer to perform a task better than a human would, humans can think for themselves and require less direction. Therefore to further improve the help robotics can provide, Artificial Intelligence (AI) technology and Automation is a key to improving efficiency. There are different stages of autonomy. Teleoperation, which is remotely operated, which process information externally. Semi-autonomous such as the Mars rovers, which do some processing internally. Then fully autonomous, for instance, the Roomba which doesn't need any external processing, and works by themselves. AI can provide the computer with the software to understand and more importantly learn. This 'learning' can have robots be able to be able to think for themselves, decide the best action to take, and possibly create ideas which couldn't have been thought of by a human and create better and more robots or software. Therefore improve technology and consequently improve and evolve society.

To further improve society however it has been theorised that humans and computers work better together than separate. A physical example of this is the 2005 Hyrda Chess tournament, a tournament which allowed chess players to use machines to help with calculations. The powerful computer was good, A grandmaster playing with a machine was better, However, the team to win it was two freshmen students with a basic dell computer, who was more effective at integrating machine assistance. This shows the importance of human and computer interaction.

In research for Augmenting Human Intellect, Doug Engelbart created the basis for a mouse, word processor and the emailing system. This allows for humans to be more efficient, by optimising user interface. He described 'Artifact Processes' the computer, 'Human Processes' the human, and the interaction 'Man-Artifact Interface'. These systems have had a massive impact on we do any task. For example, this essay would have taken a much greater amount of time to write up, and research wasn't it for the use of a mouse or a Word processor. To further this idea of a connection between humans and computers, Mark Weiser theorised in his book "The computer for the 21st Century", that computer will evolve to blend into every aspect of life, and soon we wouldn't notice it. He has research into Augmented Human Intellect to answer the question. How do we design and build systems that maximise the combined intelligence of human and computers? He theorises that this is possible not by building the best computer, but with the best system.

This ideal can be represented in this graph (Figure 3), the evolution of humanity has plateaued over the many hundreds of years, while the computer has an exponential growth stated by Moore's Law, which describes the number of transistors has double every two years. Therefore through the use of computation, we could see also an exponential improvement in humanity's evolution. Computations can be done physically with the use of cyborgs, or by improving interfaces for businesses and daily activities. The importance of interfaces in pointed out in this quote, The needs of the users should dominate the design of the interface, and the needs of the interface should dominate the design of the rest of the system.' (Norman 1986). As far as the user understand the user interface is the computer, not the hardware. Therefore, the interface is key.

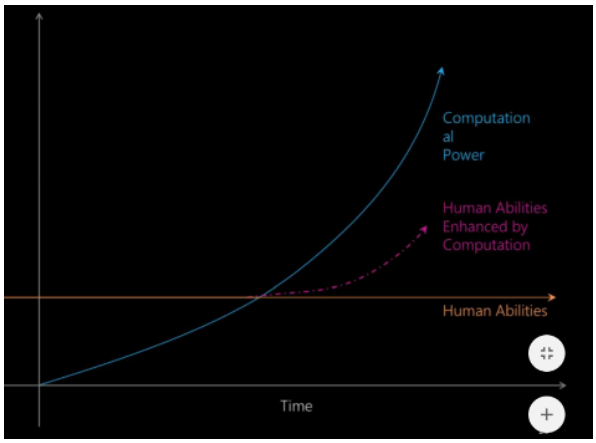


Figure 3: Lecture 11 Human-Computer Interaction Slides

Combining both robotics and human-computer interaction we could create an improved version of society, this can be done with firstly User Customization, the basis that if users could tailor their applications to their own needs, they will be able to more efficiently use the applications, and increase the connectivity between the user and the computer. Another is Embedded Computation, which is placing computer and automated processes into everyday life, from computerised cooking to automatic blinds. This will help towards Mark Weiser theory of computer being in every aspect of life. An addition to this is the ever-growing interest in Augmented Reality, augmenting aspects of vision to improve daily life, such as real-time statistic to a user performing a difficult task, such as construction, or for personal entertainment like PokemonGO. Another is understanding the way humans interact with social media/internet, to gather information about Social Computing, which will help towards knowledge-driven human-computer interaction, to understand the semantic gap between human and computers. This understanding can greatly improve how humanity performs a task, and completely change how society interacts with the world and each other. This is again another reason why the essence of computer science is to improve society.

By the studying of this course, there is a common theme between each lecture. Improve. Each lecture described how they were using computer science to improve an area of society. From improving how we analyse and store language to predict the future or understand the past. To using Speech technologies and compression to improve further how we communicate with computers and society. Improving robots to further help humanity in manufacturing, analysing and processing of the world. Lastly how computer sciences are using a computer to improve society by increasing the ease of interconnectivity between humans and computers. I agree with Mark Weiser, one day I think computers and humans will have evolved into total connectivity, and soon computers won't be recognisable as separate to us. Due to the theme and ideal, I believe that the essence of computer science is to improve society.