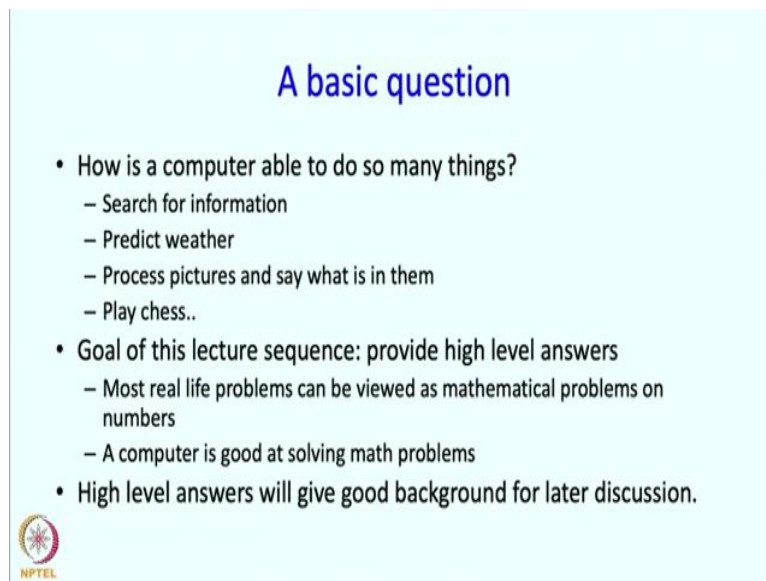


**An Introduction to Programming through C++**  
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**Department of Computer Science and Engineering**  
**Indian Institute of Technology Bombay**  
**Lecture No. 02 Part - 1**  
**Problem Solving Using Computer**

**Introduction. Real life problems as math problems.**


Hello, welcome to the second lecture sequence of the first week of the NPTEL course on an introduction to programming through C++. I am Abhiram Ranade and the reading for this lecture sequence is chapter 2 of the textbook. So in this lecture, we are going to ask some basic questions, really one basic question and provide some very high level answers to it.

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**A basic question**

- How is a computer able to do so many things?
  - Search for information
  - Predict weather
  - Process pictures and say what is in them
  - Play chess..
- Goal of this lecture sequence: provide high level answers
  - Most real life problems can be viewed as mathematical problems on numbers
  - A computer is good at solving math problems
- High level answers will give good background for later discussion.

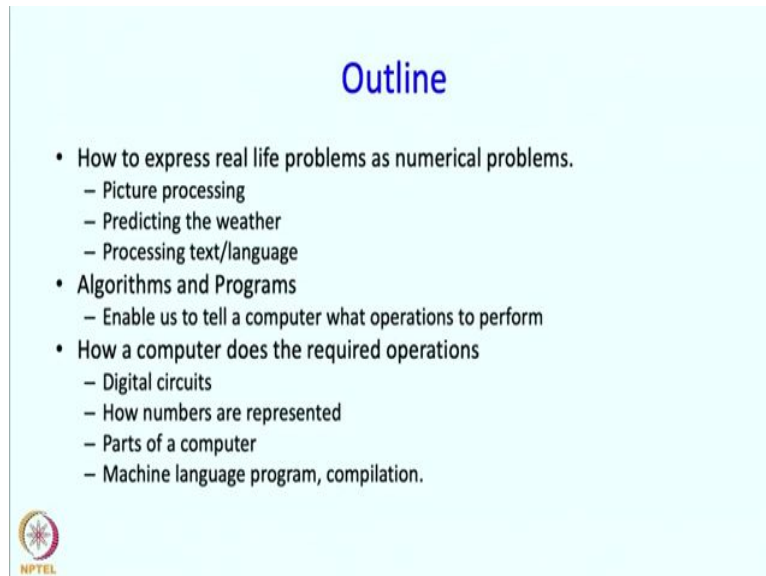


So basically the question is, how can a computer do so many things? It can search for information, predict weather, process pictures, play chess. In this lecture we want to provide some high level answers, not detailed answers. But certain just sort of make things plausible. So, all these tasks seem too difficult and too unbelievable, so we are going to provide you just the small amount of information which will make them seem a little bit more understandable.

So, the answers are going to be of the following kind, we are going to argue, we are going to propose really, not a detailed argument, we are going to propose that most real life problems can be viewed as mathematical problems or problems on numbers. And a computer can be made to solve mathematical problems. Well this statement is a little misleading, because a computer does what it told, so if we can solve that mathematical problem, then we can tell the computer go ahead and solve it. So, in that sense a computer is good at solving math

problems. So these high level answers we are going to provide and the hope is that these high level answers will give you enough background for whatever happens later in the course.

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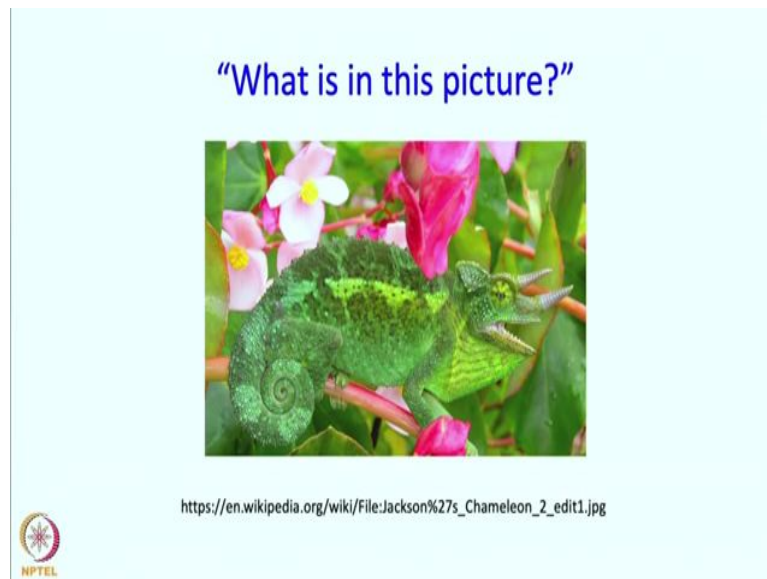
The slide is titled "Outline" in blue text. It contains a bulleted list of topics:

- How to express real life problems as numerical problems.
  - Picture processing
  - Predicting the weather
  - Processing text/language
- Algorithms and Programs
  - Enable us to tell a computer what operations to perform
- How a computer does the required operations
  - Digital circuits
  - How numbers are represented
  - Parts of a computer
  - Machine language program, compilation.

In the bottom left corner, there is a circular logo with a star-like pattern and the text "NPTEL" below it.

So here is what we do - we will see how to express real life problems as numerical problems. So we will take examples picture processing, predicting the weather and processing text or language. Then I will talk about algorithms and programs, then I will tell you how a computer really does all these things. So this will be a really whirlwind introduction to digital circuits. So a topic which can take courses in electrical engineering but we are going to again go through it at a very high level, so I will tell you how a digital circuit works, how numbers are represented using the electrical quantities. I will tell you what are the parts of a computer are and I will tell you the notion of the machine language program and compilation. So all these things together will be background material for what happens later in the course.

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So let us start with this question, so you see this colorful picture in front and if I ask you what is in this picture, you could tell me right away that there is a chameleon, by the way this is taken from a Wikipedia page. Now, we would like a computer also to do it and in fact today computers can do it, the computer will tell you that there is a chameleon.

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How to represent black and white pictures using numbers

- Suppose picture is 10cm x 10cm.
- Break it up into 0.1 mm x 0.1 mm squares
- 1000 x 1000 squares. 1 million “pixel”s
- If square is mostly white, represent it as 0.
- If square is mostly black, represent it as 1.
- Picture = 1 million numbers!

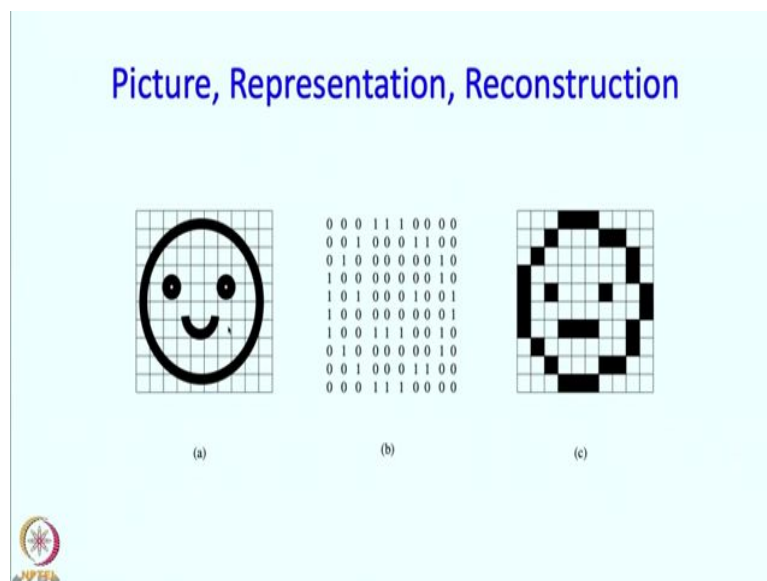
NPTEL

How does a computer do this? Well for that we need to know, how to represent pictures using numbers. So I am going to start off with black and white pictures, so how do you represent black and white pictures using numbers? Suppose I have 10 centimeter by 10 centimeter picture, so I am going to divide it into tiny squares. So each square of say 0.1 millimeter by

0.1 millimeter. So the side length is 10 cm and the side length of the small square is 0.1 millimeter. So, really there are 1000 squares on each side, so 1000 by 1000, that is the total number squares or 1 million squares or pixels are there.

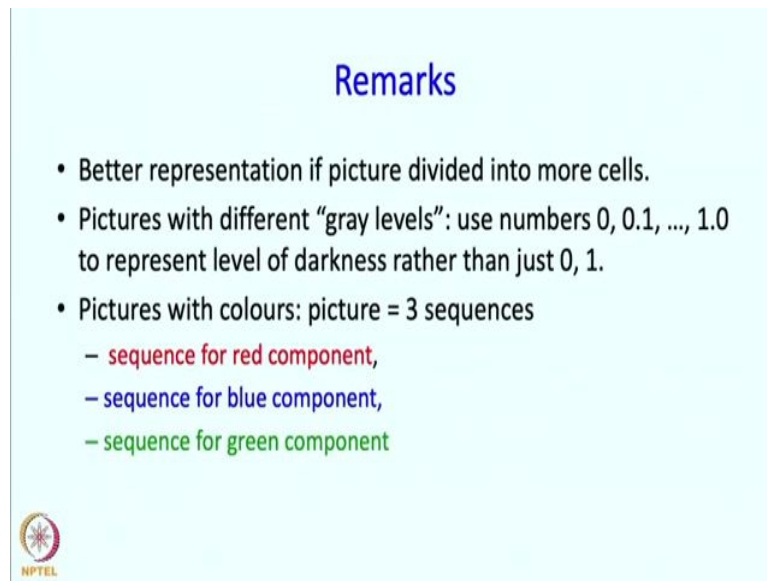
Now, if one of those million square is mostly white, we are going to represent that whiteness as a 0. If it is mostly black, we will represent it as 1. So for a 1000 by 1000 squares, in the picture we will have a million numbers. So we will have a sequence of million numbers which will represent that picture.

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Here is an example, so that smiley face on top of that I have a put smaller squares and as we can see say a square somewhere over here is mostly white, so I get a 0 over here, whereas this square is mostly black and so I get 1 over here. And so in this manner I have put 1's and 0's. So this is going to be representation of this picture. Now, I would like to note this representation is not perfect. So really, if you give me this, I will be able to say that look the picture could be something like this as well. And this is not really the same as this picture, but it is close enough. And in fact you can observe that if I make the square smaller and smaller I will get a better and better representation of this picture.

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**Remarks**

- Better representation if picture divided into more cells.
- Pictures with different “gray levels”: use numbers 0, 0.1, ..., 1.0 to represent level of darkness rather than just 0, 1.
- Pictures with colours: picture = 3 sequences
  - sequence for red component,
  - sequence for blue component,
  - sequence for green component



So, if instead of having 1000 by 1000 pixels I divided into a million by million pixels, then I will get a nearly perfect representation. In fact, it turns out that really 1000 by 1000 is not bad, your screen, this screen for example is probably something like 3000 by 2000 or something like that. And yet you cannot make out that it is made up of small squares.

Then other things are also possible. So, a square may not be completely white or completely black, so there may be some gray levels, so instead of using 0 or 1, you could also use the numbers 0, 0.1, 0.2 and so on. So you might have different gray levels, so numbers to represent different gray levels, so your number are not just 0's and 1's, so it is not just sequence of 0's and 1's, but sequence of 1 of 10 numbers whatever or whatever 11 numbers.

What if we have color? Well, colors can be broken down. So a picture now is going to made up of 3 sequences - a sequence for the red component, a sequence for the blue component and a sequence for the green component. The actual colour is made up by adding these components. So, that is how a picture is represented.

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## Computer vision/Image processing

**Input:** sequence P of 1 million numbers (0 or 1)

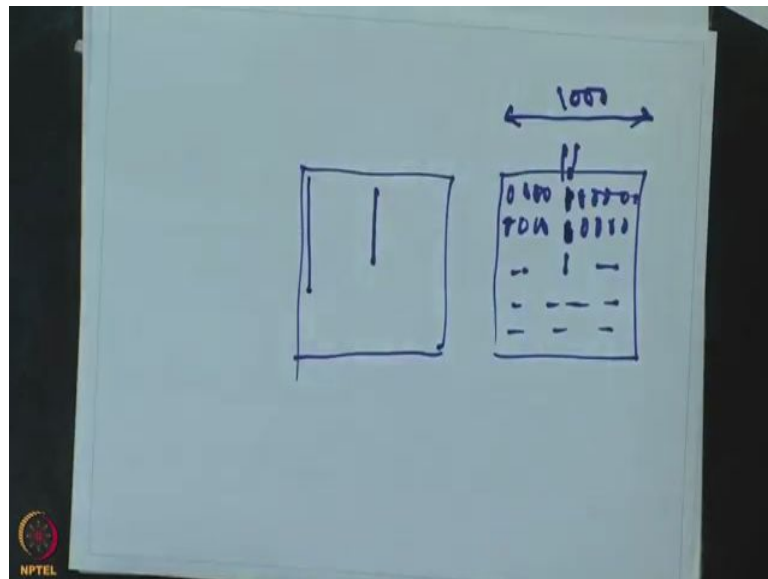

- Representing a 10cm x 10cm black and white picture,
- Given in left to right, top to bottom order.

**A very simple image processing problem:**

- Is there a vertical line in the picture?

**Expressing the problem mathematically:** What property does the sequence need to have if it is to contain a vertical line?

- All 0s, except for 1s in consecutive rows of some column
- Going down a column = move 1000 positions in the sequence
- 1s in positions  $i, i+1000, i+2000, i+3000, i+4000, \dots$  for some  $i$
- "Is there a vertical line?" = "Does sequence P satisfy above property?"



Now, what can we do with such pictures? Well, we can ask questions like is there a chameleon in it or what is in it? Alright, so typically what do these problems look like? So we are given as input a sequence let us call it P of a million numbers and let us take our simplistic picture which is a black and white picture 1000 by 1000 pixels. So there are a million numbers 0 and 1 and these pixels are given to us in top to bottom, left to right order.

So these are representing a 10 cm by 10 cm black picture given in left to right top to bottom order. Like the way you would write text on that page. Now, instead of worrying about chameleons, let me pose a very trivial, not even a problem which might be of interest to a

child, but a really, really trivial problem. What is that problem? Is there a vertical line in this picture?

So let me draw it, here is my picture and suppose there is a line in it so I am asking is there a vertical line? That is all, that is all that I am asking. So, what do you do with such a question? How do you represent this question using numbers? So, you have to ask what properties does the sequence need to have, if it is to contain a vertical line? Well if I take this picture and convert it into numbers, what is going to happen? So I am going to get lots of 0's but suddenly there might be a 1, again lots of 0's, then lots of 0's over here, then there is a 1 in the same column, lots of 0's, 1 in the same column, 0's here, 0's here, and may be all 0's here.

So the point is that there is a 1 for some rows, some consecutive rows of some column, alright? So, can I describe what pattern this sequence of 0's and 1's is going to possess? Well, here is the pattern, suppose, the first 1 is in the  $i$ th position, where is the next term going to be? Well how many steps are you going to go from here to here? So you will go all this distance, you will go all this distance.

Remember that there is a 0's and 1's are given to you in the left to right top to bottom order. So if an 1 occurs in the  $i$ th position the next 1 will appear in the  $(i+1000)$ th position because this distance is 1000. The 1 after that we will appear in the  $(i+2000)$ th position,  $(i+3000)$ th position and so on.

So in fact, that is exactly the pattern. So there are going to be 1's a position  $i$ ,  $(i+1000)$ ,  $(i+2000)$  and so on for some  $i$ . So at this point, we have described what it means in mathematical terms for there to be a vertical line. So, is there a vertical line is as good as saying does the sequence  $P$  of 1's and 0's satisfies this property, that for some  $i$  there are 1's in positions  $i$ ,  $(i+1000)$ ,  $(i+2000)$  a few such entries.

Now, how do you solve this problem? So this problem is actually quite easy, you can try out different values of  $i$ . So you can check is there this pattern valid for  $i$  equal to 0, if it is valid for  $i$  equal to 0 that is as good as saying that there is a pattern right here, there is line right here. So, this effectively for different values of  $i$  will give you different lines and then if you find that is for some values of  $i$  this pattern is actually there, then you can claim, yes, I have found the vertical line.






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### Does the picture contain a chameleon?

- In principle, same as asking whether the picture contains a single vertical line:
  - Identify a set of properties that the sequence of numbers representing the picture must satisfy if the picture contains a chameleon.
  - Identify computations that can check if the given number sequence satisfies the required properties.
- In practice requires enormous ingenuity
- Main concern of the deep subject “Computer Vision”




Now the question, does this picture contain a chameleon, in principle is identical, why? Again you need to identify a set of properties that the sequence of numbers representing the picture must satisfy in order for the picture to contain a chameleon. These properties will be really complicated, but some properties will have to be identified, there is no escape in this step. Then, you will have to decide, how do I check whether these properties are satisfied? Again this is a difficult mathematical problem, but it can be solved. And, in principle, it is the same problem that we solved. That problem was a trivial problem, but again for the vertical line, but again the problem was similar in principle that you needed to identify a set of properties and you needed a procedure for checking whether the pictures satisfied those properties.

So in practice this requires enormous ingenuity, but people have displayed that enormous ingenuity. In fact, this is the main concern of a deep subject called computer vision. We are certainly not going to study computer vision in this course, but all that I wanted to point out you was how basically that subject works. That subject works by representing pictures in terms of 0's and 1's, by associating a property where that sequence of numbers has to have if it is to contain a certain object, and designing computations which will decide whether that property is satisfied by a given picture.

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### Weather prediction

- Divide the surface of the earth into small regions (like pixels).
- Let  $p_i$ ,  $t_i$ ,  $h_i$  = pressure, temperature, humidity in region  $i$
- Laws of physics tell us how the values will change with time.
- We can measure current pressure, humidity, temperature values, and calculate what will happen tomorrow!
- Smaller the regions, better will be the accuracy. (Smaller the pixels, better will be the picture representation).



Let us turn to one more interesting problem you hear the weather report and you may wonder, how they do that? So here is what happens, again at a very, very high somewhat superficial level. So they divide the surface of the earth into small regions, just like you divide the picture into pixels. And for each region, you are going to have variables say  $p_i$ ,  $t_i$ , and  $h_i$  which represent the pressure, temperature and humidity in that region.

Now, we know enough physics to say that if you tell me the pressure, temperature, and humidity in a certain region and not just in a certain region, but the regions nearby, so adjacent regions or regions which are not too far something like that. Then I can calculate, by using laws of physics which are mathematical in nature, what the future temperature, pressure and humidity are going to be. So, if we measure the current pressure, humidity, and temperature then we can calculate what happens, say, 1 second from now on, but then we can calculate 2 seconds, 3 seconds and we can eventually calculate what will happen tomorrow

Now, I have greatly simplified what is actually going on, but what is going on is in essence this. So we are using physics, we are talking about values of things like pressure, temperature, humidity and we are using laws of physics to say how they are going to change. And this requires lots of computations, but that is what computers are for.

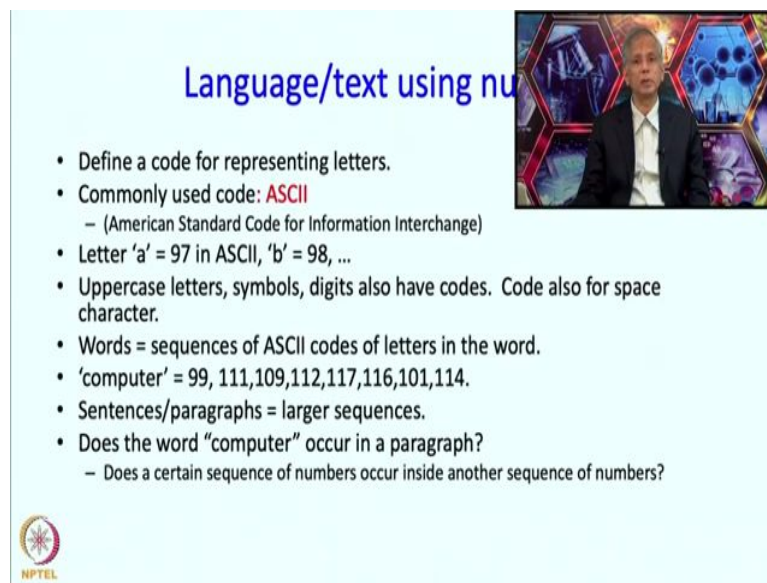
Again like picture processing, if we make those regions smaller and smaller, then we will get better accuracy, why? Because if a region is large, then it does not make sense to ask what is the temperature in that region because in one part of the region the temperature might be

high, in another part the temperature might be low, but if the region is really tiny then you can say roughly it is the same temperature in that entire region just like picture processing.

So if you make the region smaller than that means are actually having to do more calculations. But again as i said that is what computers are for.

Computers can also process the language of course they we can do searches and you might be wondering, how to they do that? Well here is a very simple scheme, again this is too simple. Lot more sophisticated things happen, but let me just tell you one plausible idea.

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The slide is titled "Language/text using nu" in blue text. It features a list of bullet points on the left and a video inset on the right showing a man in a suit speaking. The video inset has a hexagonal border with various images inside. The NPTEL logo is in the bottom left corner.

- Define a code for representing letters.
- Commonly used code: **ASCII**
  - (American Standard Code for Information Interchange)
- Letter 'a' = 97 in ASCII, 'b' = 98, ...
- Uppercase letters, symbols, digits also have codes. Code also for space character.
- Words = sequences of ASCII codes of letters in the word.
- 'computer' = 99, 111, 109, 112, 117, 116, 101, 114.
- Sentences/paragraphs = larger sequences.
- Does the word "computer" occur in a paragraph?
  - Does a certain sequence of numbers occur inside another sequence of numbers?

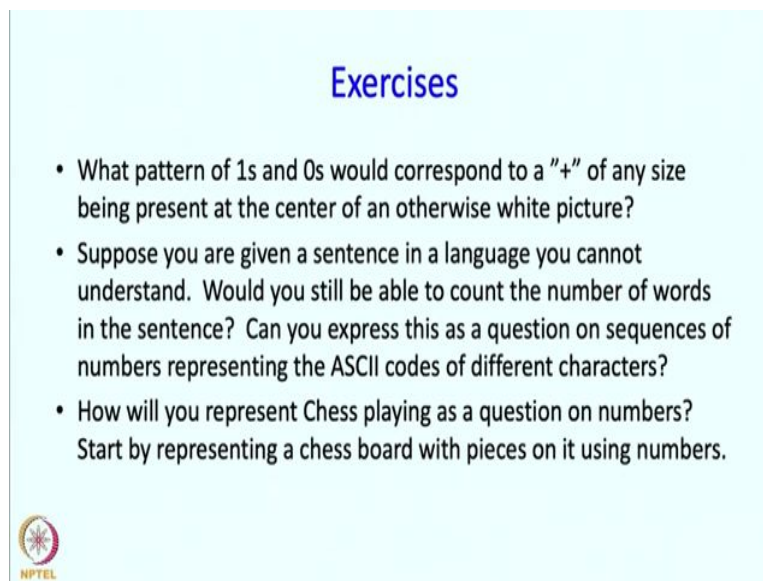
So first, we begin by defining the code for representing letters. And the code that is commonly uses is the so called as ASCII code which stands for American Standard Code for Information Interchange. In this code the little a letter is represented by the number 97, the little b is represented by 98, the little c by 99 and so on. So consecutive numbers are given for consecutive letters, lower case letters and similarly, some numbers are given for uppercase letters as well.

And not only letters but symbols say the equality symbols has an ASCII code, digits also have ASCII codes, so 9 as number is different from 9 as a symbol that use on the screen. And the space character also has an ASCII code. So what is a word? A word can be thought simply as a sequence of ASCII codes for the letters in that word. So 'computer' for example can be represented by the ASCII code for 'c-o-m-p-u-t-e-r'. If you check, 99 is the code for c, in fact, it is the next code after 98 which we said the code for b, so clearly it is the code for c,

but if we check the rest of the numbers are in fact consistent with this idea and they are in fact the codes that are used in ASCII.


So a word is a sequence of numbers, what is a sentence or a paragraph? Well there are simply larger sequences. Now, you can ask, does the word computer occur in a certain paragraph? What is that question? That question is simply the question, does a certain sequence of numbers occur inside another sequence of numbers? that is it. So if you can answer queries like this very quickly, you can do searching for words in books, or webpages, or whatever you have.

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**Exercises**

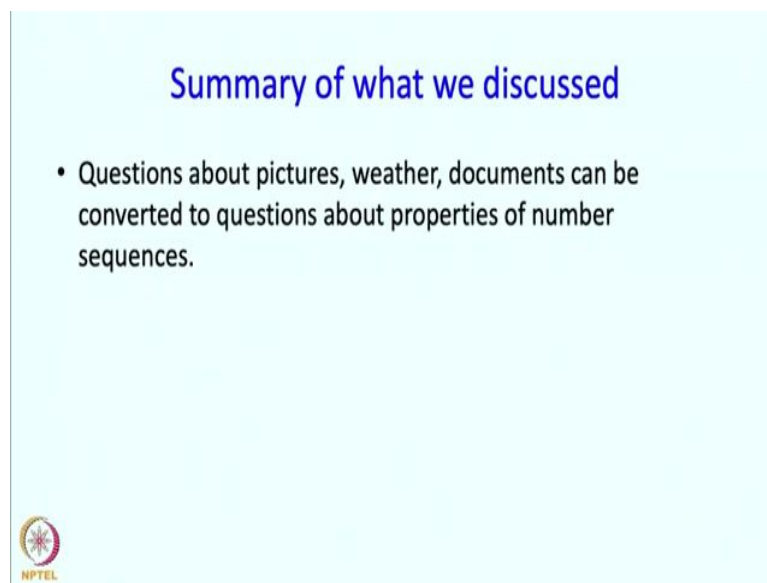
- What pattern of 1s and 0s would correspond to a "+" of any size being present at the center of an otherwise white picture?
- Suppose you are given a sentence in a language you cannot understand. Would you still be able to count the number of words in the sentence? Can you express this as a question on sequences of numbers representing the ASCII codes of different characters?
- How will you represent Chess playing as a question on numbers? Start by representing a chess board with pieces on it using numbers.



Alright, so here are some thought exercises that I would like you to do. So, these are mental exercises, I just want you to think about it, because these are the kinds of questions we are going to ask later on, and later on we will try to have very precise answers. So for example, we talked about how do you represent the fact that a certain picture has a vertical line? Well in a similar manner I would like you to think about what patterns of 1's and 0's would correspond to a plus of any size being present at the center of an otherwise white pictures? Another question that I would like you to think about is, suppose you are given a sentence in a language you cannot understand, but you are given ASCII codes. Would you still be able to count the number of words in the sentence? So could you express this as a question on the sequences of numbers representing the ASCII codes of the different characters?

How will we represent chess playing as the question on numbers or how will you represent a chess position, for example? So once you can express a chess position as a number, then you have a foot in the door to asking questions about oh what is next good move? What does it means for the white rook to capture a certain pawn or something like that, when can a rook capture upon? So those questions will start becoming amenable to analysis once you first decide, what does it mean to represent to chess position?

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So, what have we discussed? We have said that questions about that pictures, weather, documents can be converted to questions about properties of number sequences. And these are just examples, the implications is, that basically any question we should check whether it can be converted to a question about numbers and that is when we can solve those questions on a computer. But answering these questions requires solving interesting math problems, so it does require a lot of ingenuity. So we will stop here, and take a break.