Mathematica - The Principles of Math
5. A Binary World of Zeroes and Ones

09:22 minutes

00:29 What if there exist only two numbers, 0 and 1 in the world?

00:37 Let's embark on a journey into a binary numeric world, one which uses only zeroes and ones.

00:52 All right, everyone, let's count out some numbers!

01:00 We count numbers using a ten-based system of numbers from zero to nine.

01:05 (caption) What is the decimal number system?
a numeral system with 10 as the base, going from 0 to 9.
Each number place multiplies the digit in it ten times.

01:19 But if you have just one hand, how can you count large numbers with it?

01:24 For example, if you count votes for class president…

01:28 …you may have tallied up votes in groups of five.

01:33 This method of counting is called a quinary system.

01:41 There's also a duodecimal system. A box filled with a dozen pencils is a classic example of a duodecimal system.

01:50 The clock we see every day is based on twelve hours. There are twelve months in a year. These are all examples of duodecimal counting.

02:01 And then there's the binary system.

02:04 We usually don't consciously recognize the existence of the binary world, but we use it a lot in everyday life.

02:05 (caption)
one pair
two pairs
three pairs

02:10 In fact, we are able to express natural numbers using a binary system.

02:10 (caption)
one pairs of shoes
two pairs of shoes
three pairs of shoes

02:17 (caption)
one pair of gloves
two pairs of gloves
three pairs of gloves

02:26 (caption)
decimal system

02:28 Naturally, a base-10 decimal system is the most common way we use numbers in everyday life.

02:35 The number 357 consists of the digit three in the hundreds' place, five in the tens' place, and seven in the units' place.

02:47 We can expand these in this form:

02:50 Three is in the digit in the ten-squared place, five is the digit in the tens' place, and seven is in the units' place.

03:01 As you've seen before, in the decimal system, the digits from zero to nine are used in each place. As the positions of the digits go up, the value of the place increases by ten times.

03:07 (caption)
10 times, 102 times (100 times), 103 times (1000 times)

03:22 binary system
2 times, 22 times (2*2 times), 23 times (2*2*2 times)

03:22 So how about things in the binary system?

03:25 In the binary system, only 0 and 1 are used to mark places. And when we hit the number two, we move up to the next place.

03:34 In other words, as we go up one number place, the value of that place doubles.

03:51 Let's expand the number 1000 using binary.
1 is the digit in the place that represents 2 to the third power, 0 is the digit in the place that represents two squared, and another 0 is in the place for two, and the last 0 is in the units' place.

04:08 Let's add these up with a formula using numerical powers.

04:13 1000 (read: "one-zero-zero-zero") in binary consists of 1 multiplied by two to the third power, plus 0 multiplied by two squared, plus 0 multiplied by two, plus 0.

04:30 The end result of this calculation is 8. That means one thousand in the binary system is 8 in the decimal system.

04:43 (caption)
57 in decimal → what in binary?
How do we transform decimal numbers into binary ones?

04:55 The easiest way to do this is repeatedly dividing the decimal number with 2 until the quotient becomes zero.

05:02 Dividing 57 by 2 leaves a quotient of 28 and a remainder of 1. Dividing 28 by 2 leaves a quotient of 14 and a remainder of 0. Dividing 14 by 2 leaves a quotient of 7 and a remainder of 0. Dividing 7 by 2 leaves a quotient of 3 and a remainder of 1. Dividing 3 by 2 leaves a quotient of 1 and a remainder of 1.

05:34 When the division is all over, organize the remainders of each division in reverse order.

05:42 All you need to do next for this binary expression is put the binary indicator 2 in parenthesis next to the number.

06:01 Many scholars argue that the binary system had been used even before the decimal system was discovered.

06:10 The ancient Chinese believed that everything in the world existed in harmony between two forces, Yin and Yang.

06:21 (caption)
sun and moon
male and female
land and sea

06:35 Based on the principles of Yin and Yang, an ancient Chinese text called The Oracle of the Sun defined the world and nature as divided into eight divinations by the lines of Yin and Yang.

06:34 (caption)
The Oracle of the Sun (Yi Jing)
eight divinations, Yin / Yang

06:47 The heavens, lake, fire, thunder, wind, water, mountains, and land.

06:45 (caption)
heavens, lake, fire, thunder, wind, water, mountains, and land.

07:02 Only two lines and eight divinations holding different meanings and numbers have a close relationship with the binary system.

07:11 This ancient Chinese text was introduced by a missionary to the German mathematician Gottfriend Wilhelm Leibniz in the seventeenth century.

07:20 (caption)
Gottfried Wilhelm Leibniz (1646-1716)
German philosopher

07:20 Leibniz took the Yin and Yang principle from The Oracle of the Sun and used it as a foundational theory for the invention of a modern binary theory to express all numbers with just ones and zeroes.

07:35 The binary system is clearer and simpler than decimal numbers, making it a better solution for use with machines.

07:43 For example, the signal for electricity turned on is 1, and the signal for off is 0.

07:47 (caption)
ON (1) OFF (0)

07:51 By repeating this, the binary system can simplify any complicated signal in a clear way.

08:02 (caption)
A N D

08:13 A computer may have numerous complicated circuits and chips, but they receive just two signals.

08:21 1 for electric current and 0 for none. With just these two command signals, computers can freely operate.

08:30 For example, when you press a button, it counts as 1, and when your finger is off, it's 0.

08:37 In other words, every time we click something, we send signals of 1 and 0…

08:42 …and the computers display the received signals on a monitor.

08:48 Computers may seem the most complicated devices in the world, but in fact they're created from the simplest binary system.

08:54 (caption)
The simplest numbers, 0 and 1.
The binary system and the simplest calculations.
This is why…
…the binary system is able to express everything in the world.