Unit “Naught”: Codes (part 2)

Dave Abel

April 4th, 2016

Outline

- A look at the rest of the term
- Revisiting codes
- Unit 8: Recursion

Schedule

- 4/4 - 4/10: Recursion!
  - Please do the reading this week! It's great!
- 4/11 - 4/17: Cryptography
- 4/18 - 4/24: Graphics, Guest Lecturer on Astrophysics! (Ian Dell'antonio), Comp. Biology!
- 4/25 - 4/29: Conclusions and Review

Other Things to Come

- **Python**
  - Advanced Workshop: next week! (survey in email)
  - Python “I want to remember the first workshop”: I will email the class with some practice exercises, can come to his or the HTA’s office hours to talk and review python.
  - Project Rubric will be put on the website this week (also in upcoming email)

Other Things to Come

- **New Office Hours:** Wednesday at 11am.
- **The Last Homework Assignment** (applications unit)
  - Out 4/18, Due 5/10
  - Discuss how CS has affected a topic of interest to you
  - Read some articles and write a short reflection (800-1200 words) summarizing and analyzing your chosen topic (full rubric to be released around 4/18)

Main Idea

En**code** information in a particular way, to make the information more:

(1) Secure
(2) Safe from error
(3) Compressed

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Why Do We Need Codes?

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ERRORS

Cello

Why Do We Need Codes?

ERRORS

Cello

Reason One: Come up with a *code* that helps handle errors!

Why *Else* Might We Need Codes?

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Why Do We Need Codes?

Reason One: Communication that is robust to errors!

Reason Two: Send information in *compressed form!*

Why Do We Need Codes?

Reason One: Communication that is robust to errors!

(Reason Three: keep messages secure)

Reason Two: Send information in *compressed form!*

Error Correcting Codes

- Goal One: what if our messages could *tell us* when there was a mistake?

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Suppose I send you our zip code

02906

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02906

First Idea: Repetition

- Send it twice! (or more)
- If they're the same, great!
- If they're different, ask to be sent the message again

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02905
02906

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- **Problem: may have to send messages *many times***

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- Problem: may have to send messages *many times*

Solution: can use multiple copies to recreate the original!

First Idea: Repetition

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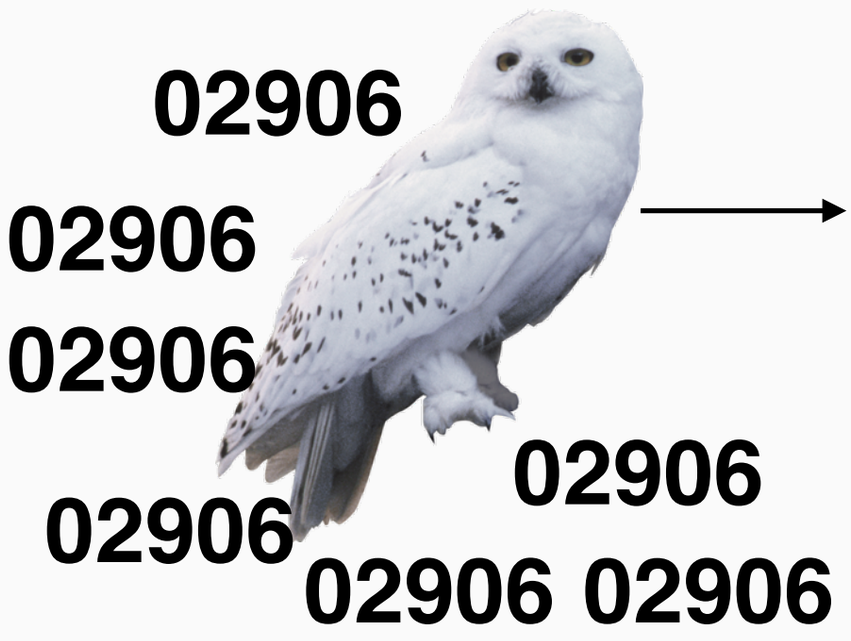

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First Idea: Repetition

Suppose I send
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02906

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02906

02905

02906

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02906

Solution: can use multiple copies to recreate the original!

First Idea: Repetition

Suppose I send you our zip code

Q: How can we recover the original from these?

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02906

02905

02906

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Solution: can use multiple copies to recreate the original!

First Idea: Repetition

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Idea: most common digit is correct

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Solution: can use multiple copies to recreate the original!

First Idea: Repetition

- Send it twice! (or more)
- If they're the same, great!
- If they're different, ask to be sent the message again
- Problem: may have to send messages *many times*
- Solution: can use multiple copies to recreate the original! Don't need to resend over and over again.
- **New Problem:** now we have to send way more stuff!

Second Idea: Checksum

- Goal: Send *less* information, but still get error-robust codes
- Idea: add some information to the message that can help detect/fix errors!

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Second Idea: Checksum

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- **Example**: 02906, the sum is 0 + 2 + 9 + 0 + 6 = 17

Second Idea: Checksum

- Checksum: add the sum of the message *mod 10* to the end!

- **Example**: 02906, the sum is 0 + 2 + 9 + 0 + 6 = 17

- So we add 17 *mod 10* to the end, which is **029067**.

- Then, upon receiving a message, we check to make sure the checksum is still correct! If it's not, we ask the sender to send another message.

Clicker Question!

- Idea: add some information to the message that can help detect errors!
- Checksum: add the sum of the message *mod 10* to the end!

Q: Is this scheme perfect? Will you *always* catch errors?

[A] Yes [B] No [C] I'm Confused

Clicker Answer!

- Idea: add some information to the message that can help detect errors!
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Clicker Answer!

5040

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5040 ⟶ 50409

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5040 ⟶ 50409 ⟶  ⟶ 50308

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Error Correcting Codes

- In a computer, communication errors happen regularly!
  - Errors in transmitting to and from the internet
  - Errors reading/writing from our computers memory
    - Old news: Errors reading/writing to CDs, floppies.
- We want to know when errors happen so we can fix them.
- Solutions:
  - Send copies! (But too much space)
  - Send a checksum!

Compression

- Idea: We can turn *big* things into *small* things that effectively *preserve the main information*.

Compression

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Compression

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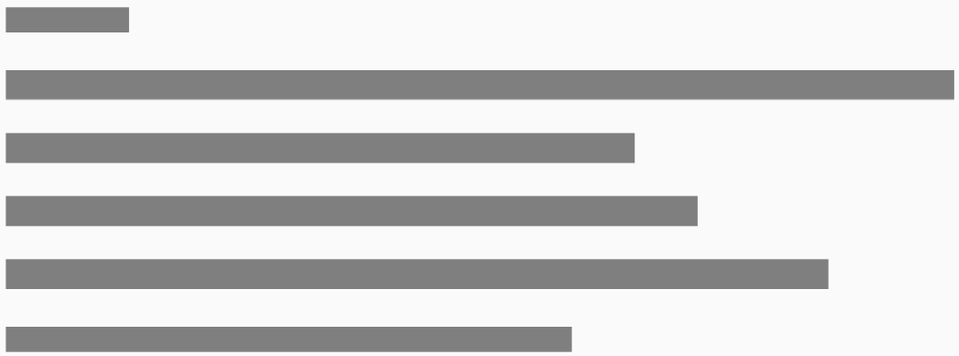
, but way bigger

Simple Explanations

Challenge 5:



Simple Explanations

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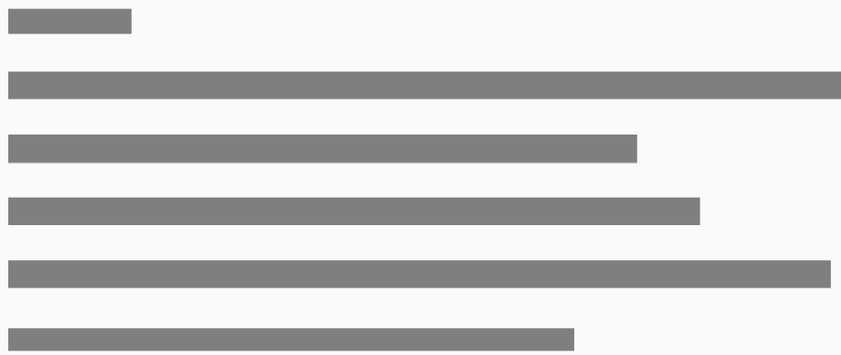
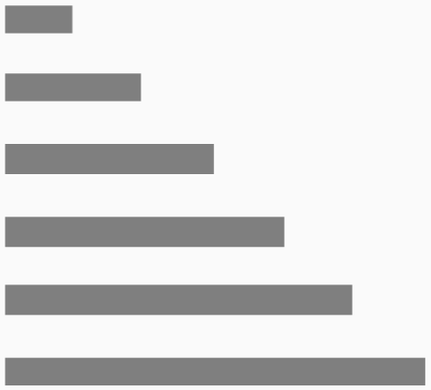


Shortest description: six bar histogram switch 2 and 6

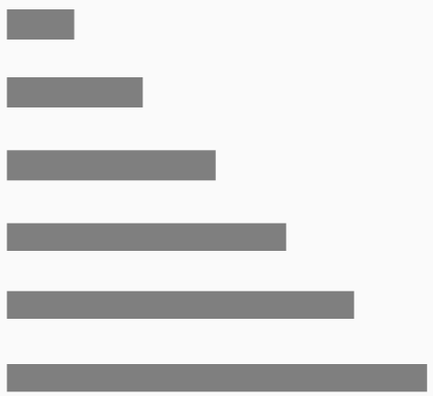
Simple Explanations

Challenge 6:



Simple Explanations

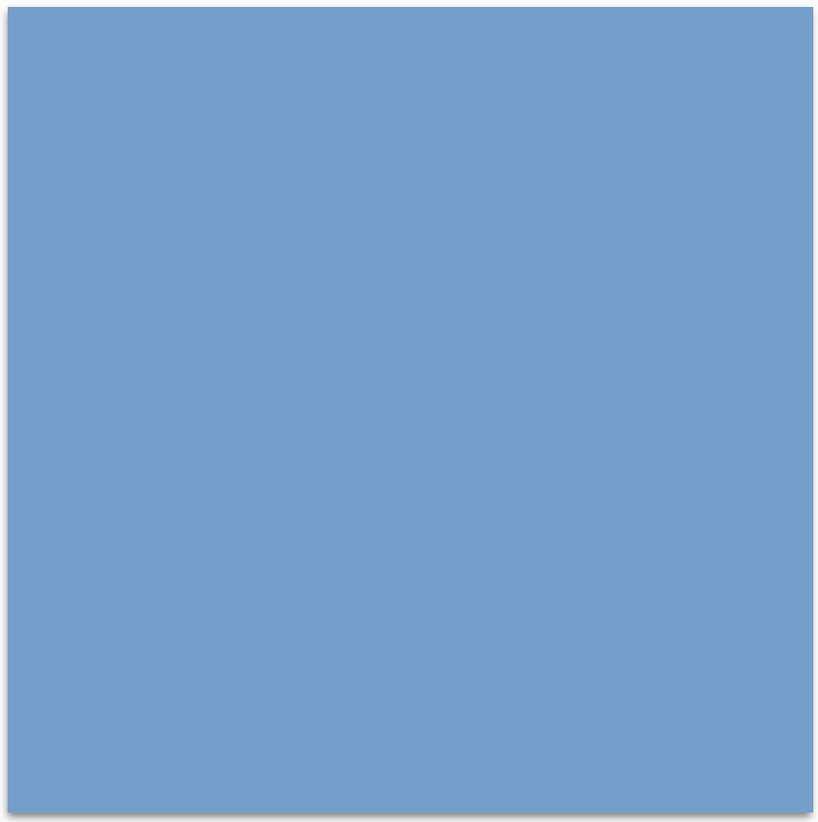
Challenge 6:

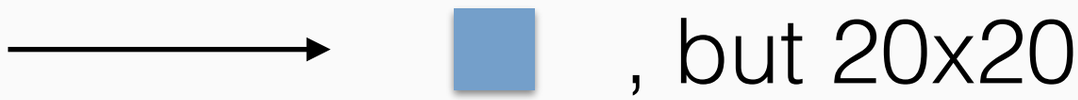


Shortest description: bars ordered

Compression

- Q: How can we make an object *as small as possible*, but still preserve what the object is?





, but 20x20

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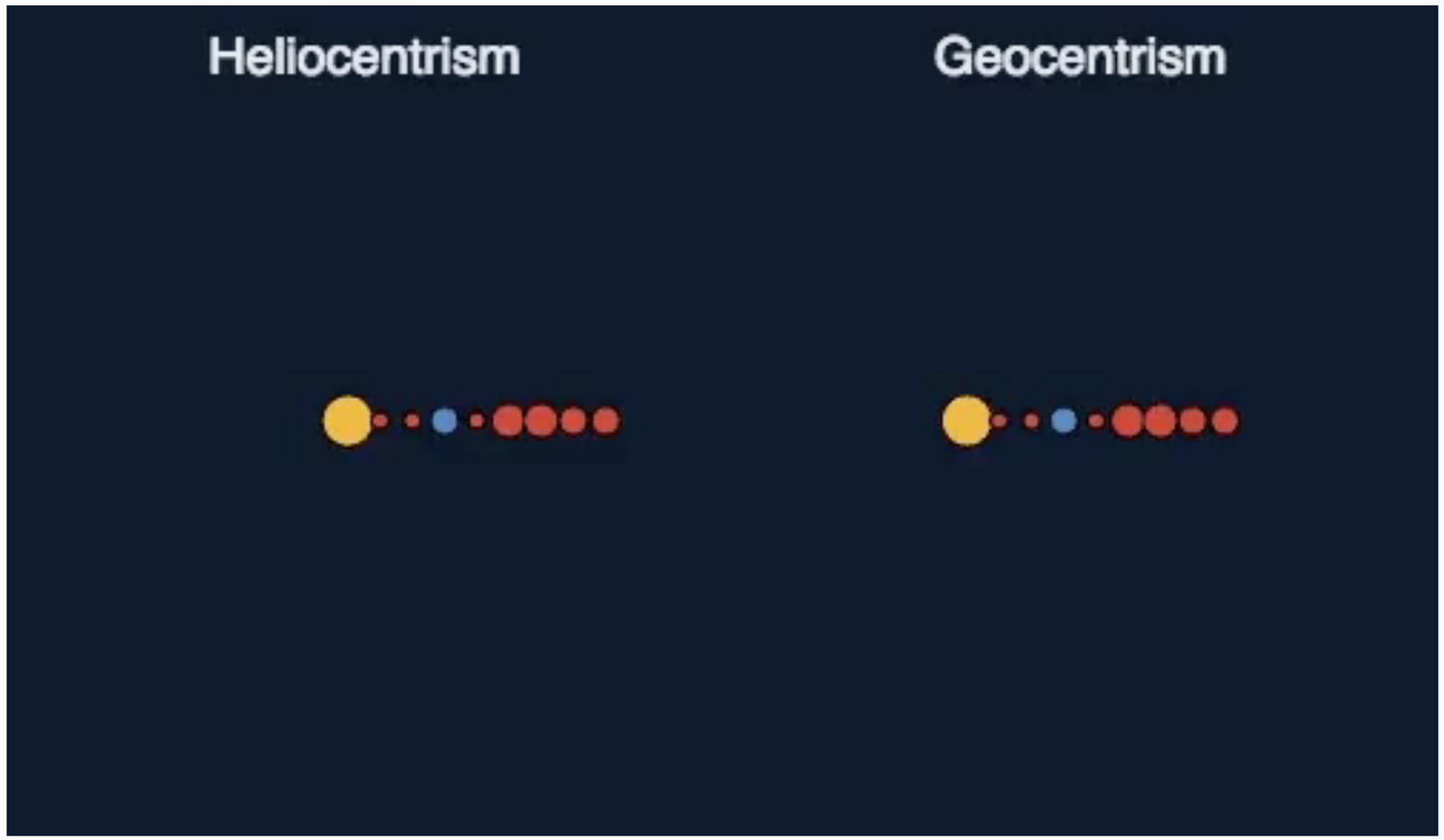
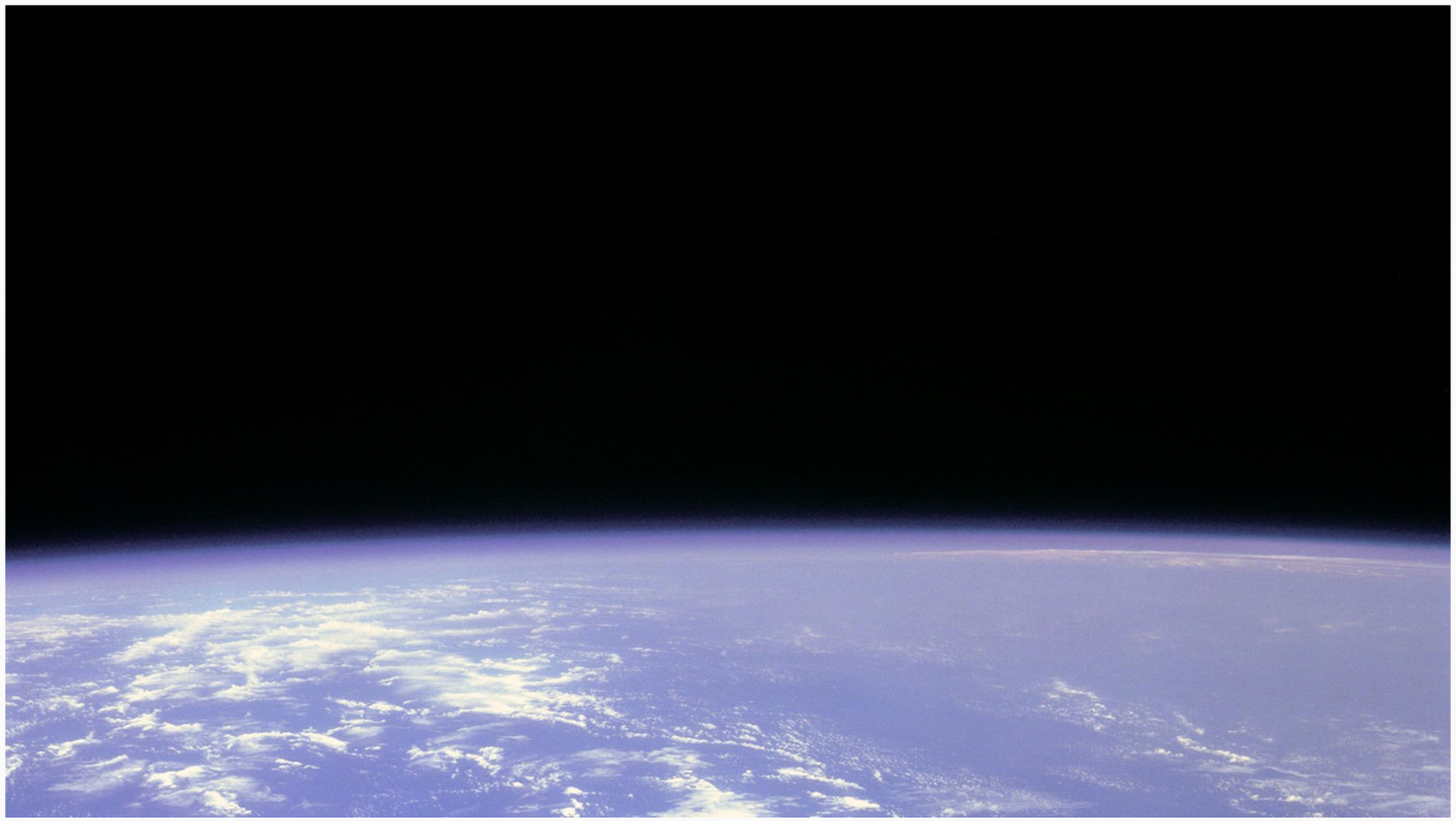


Compression: Intuition



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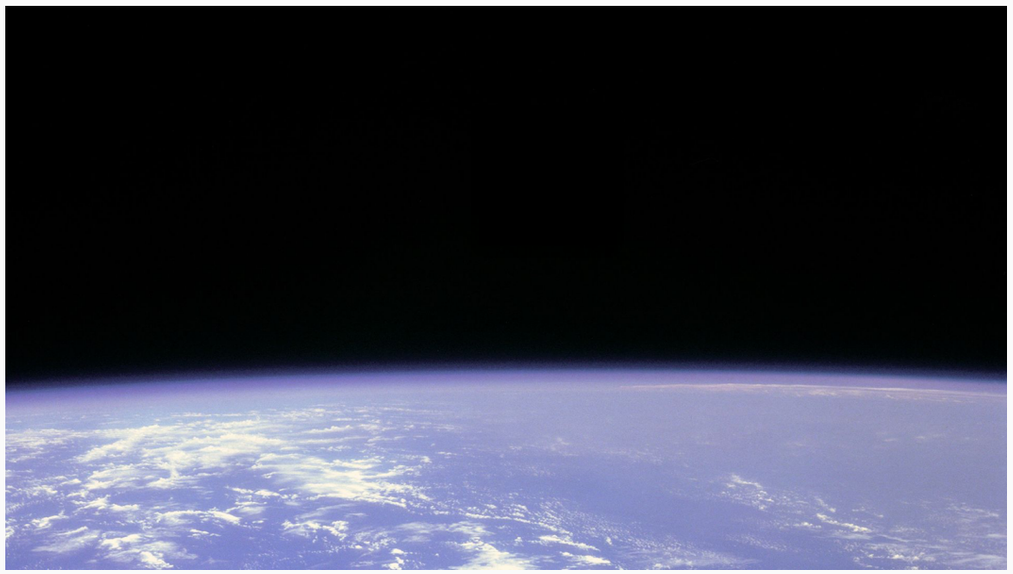

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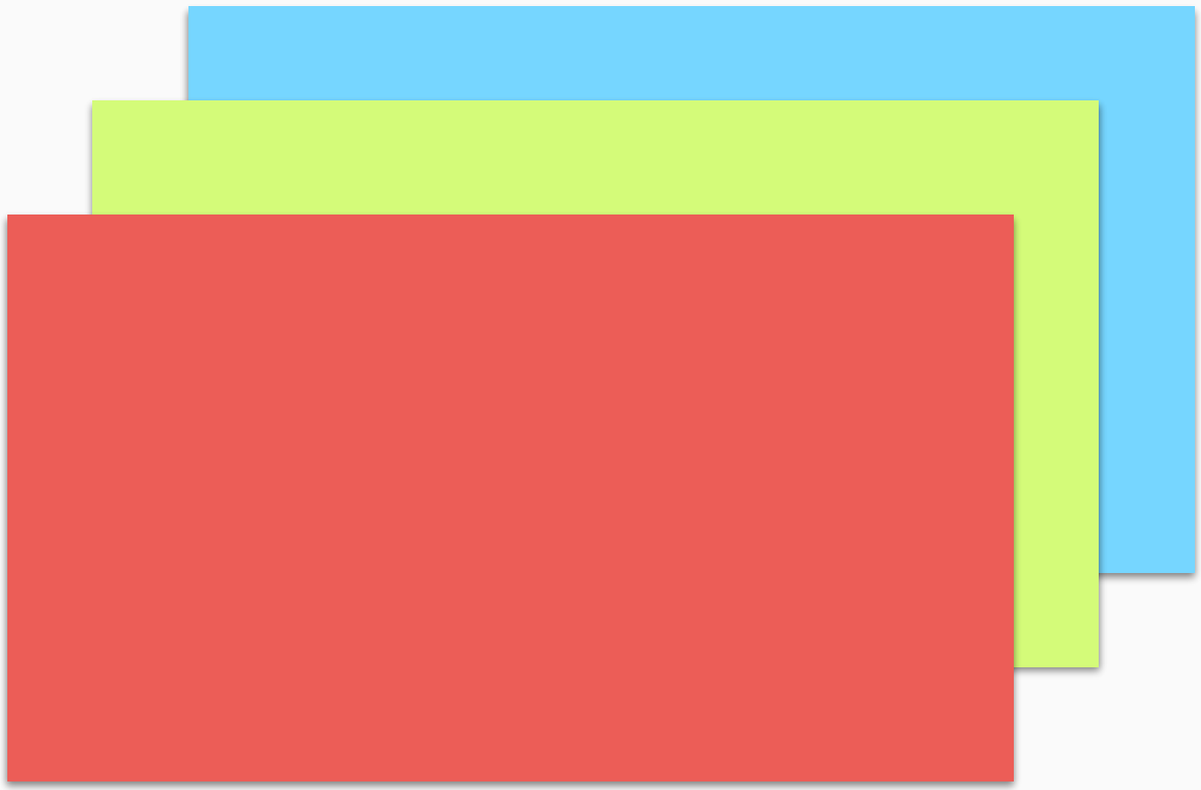

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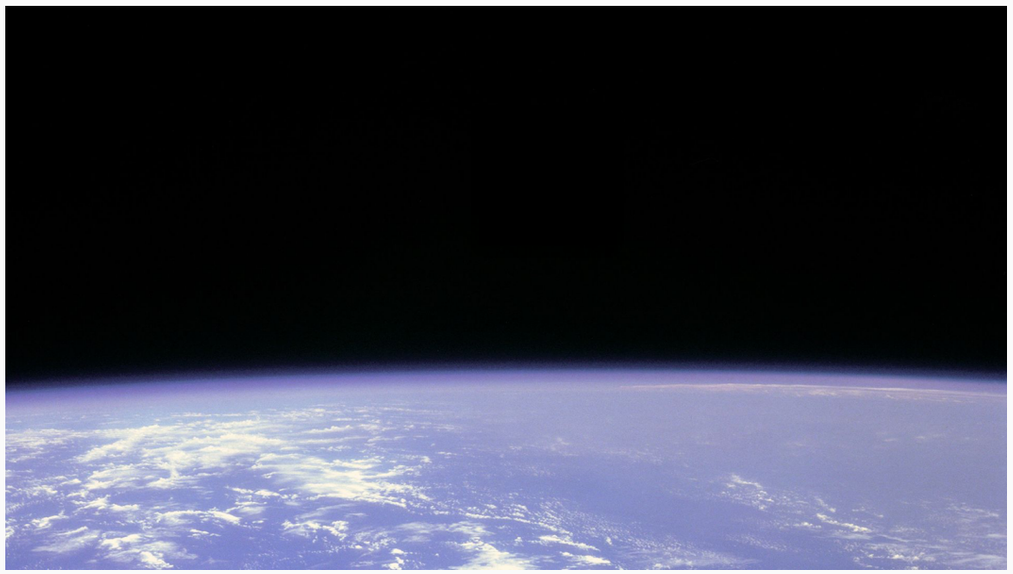

1Kb

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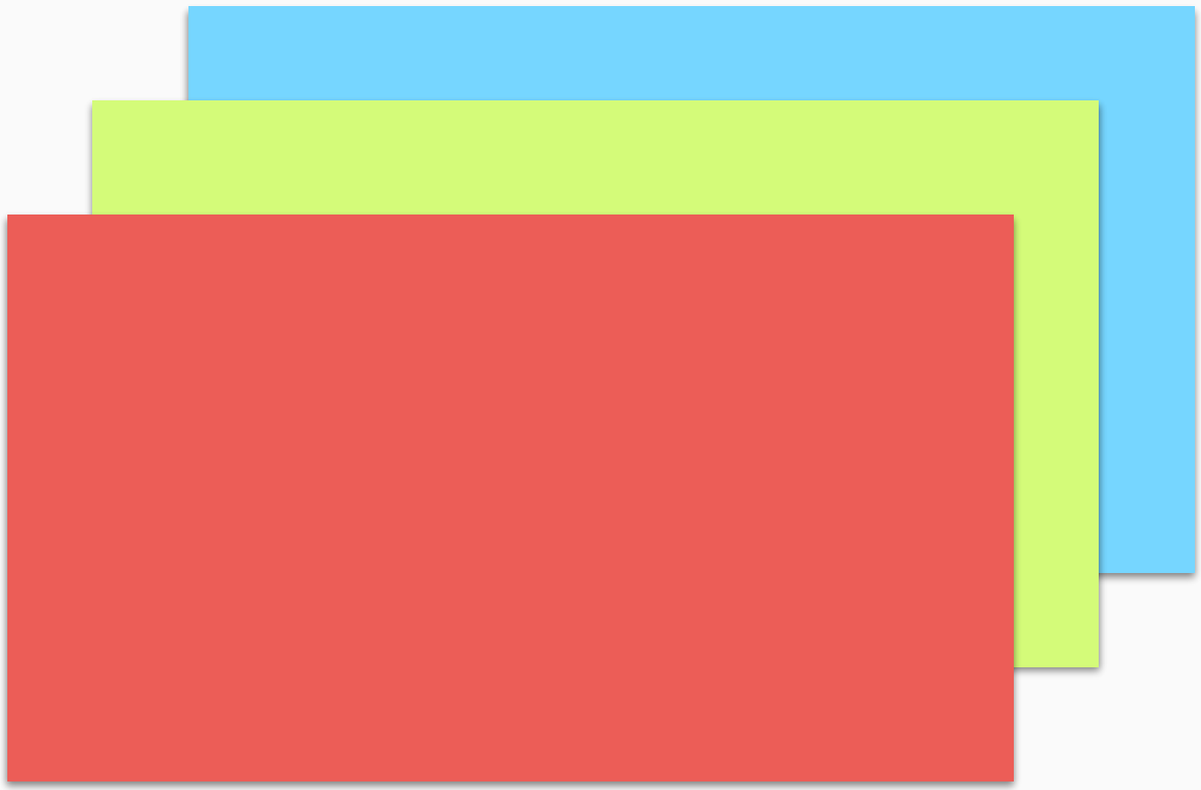

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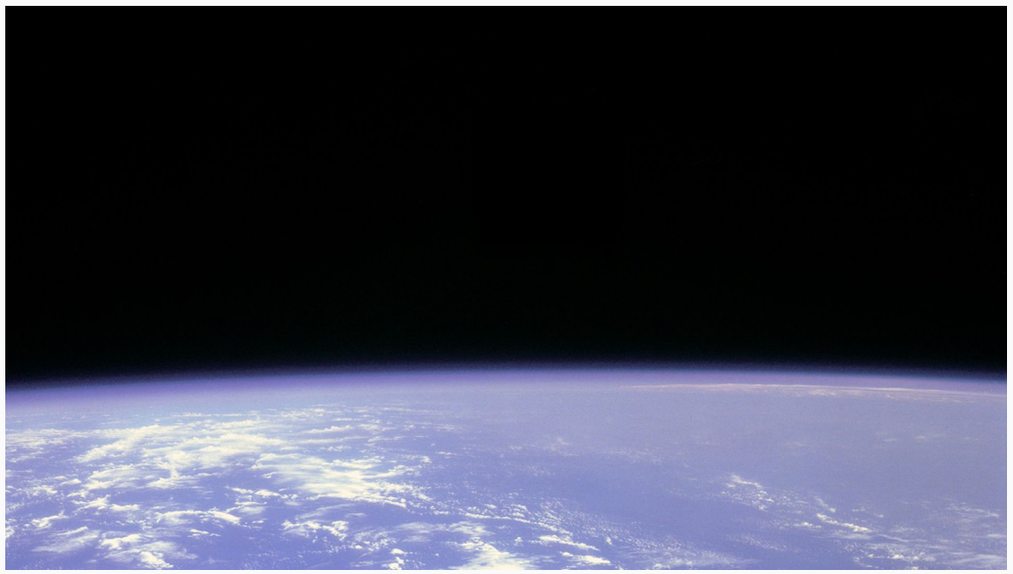

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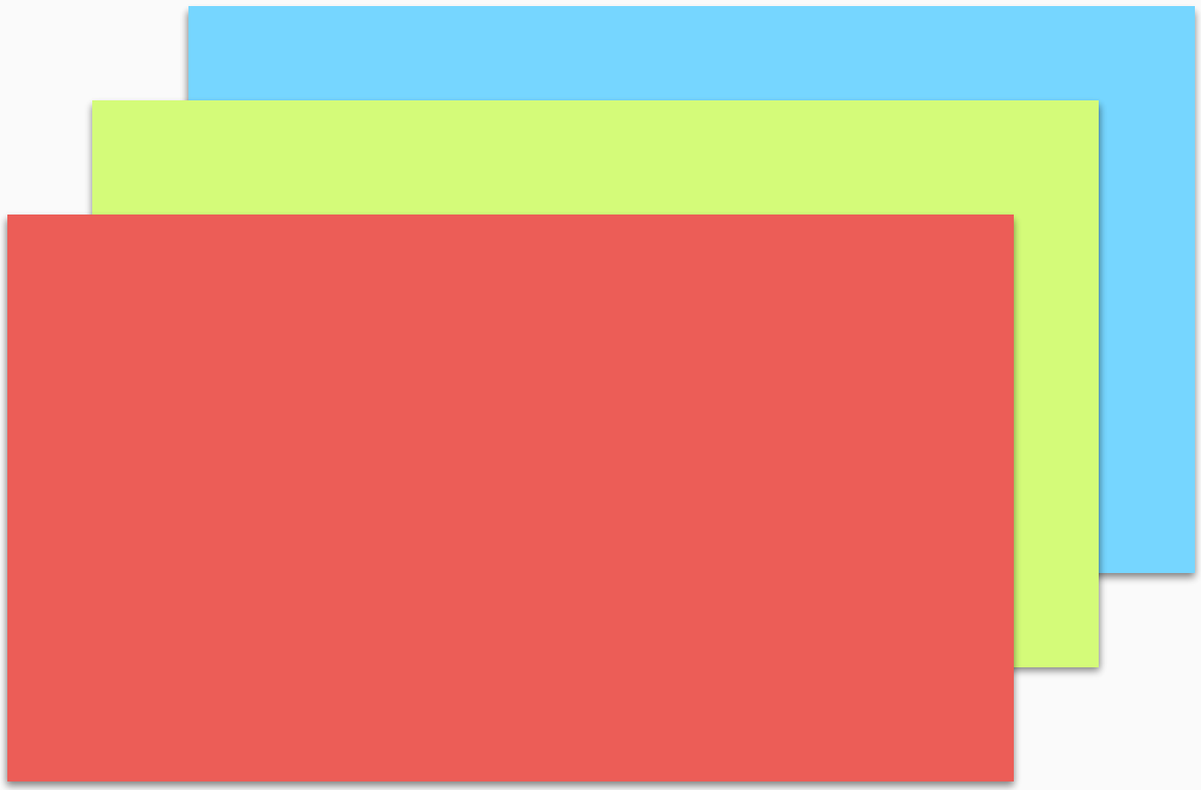

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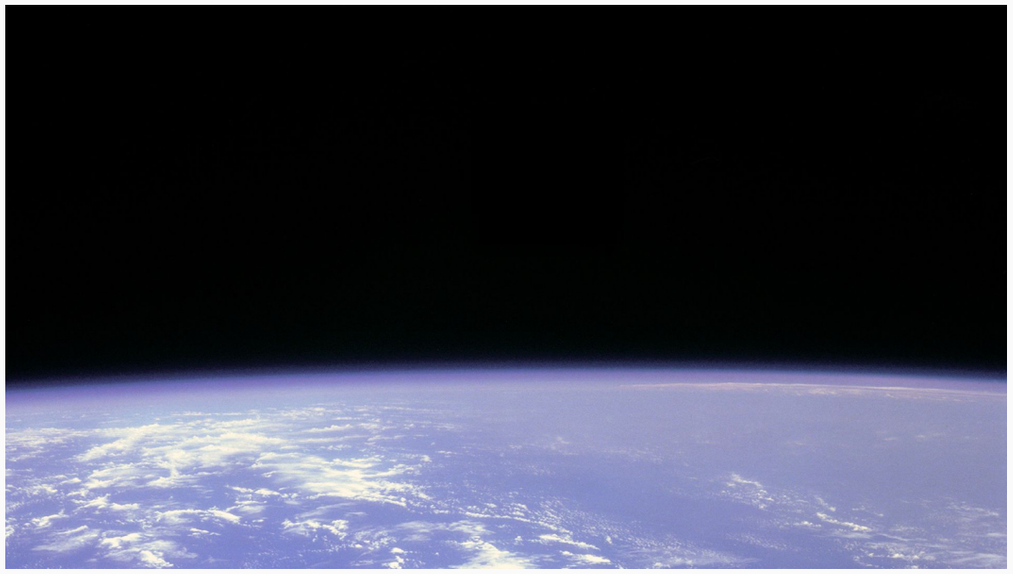


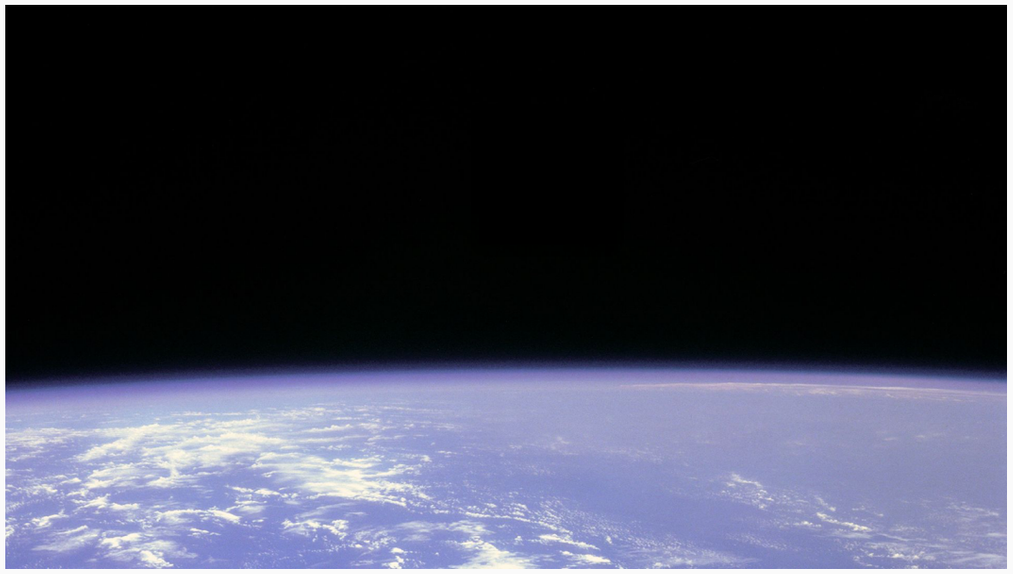
1Kb

=

Everything else, black

0.3Kb

Compression: Intuition



1Kb

=

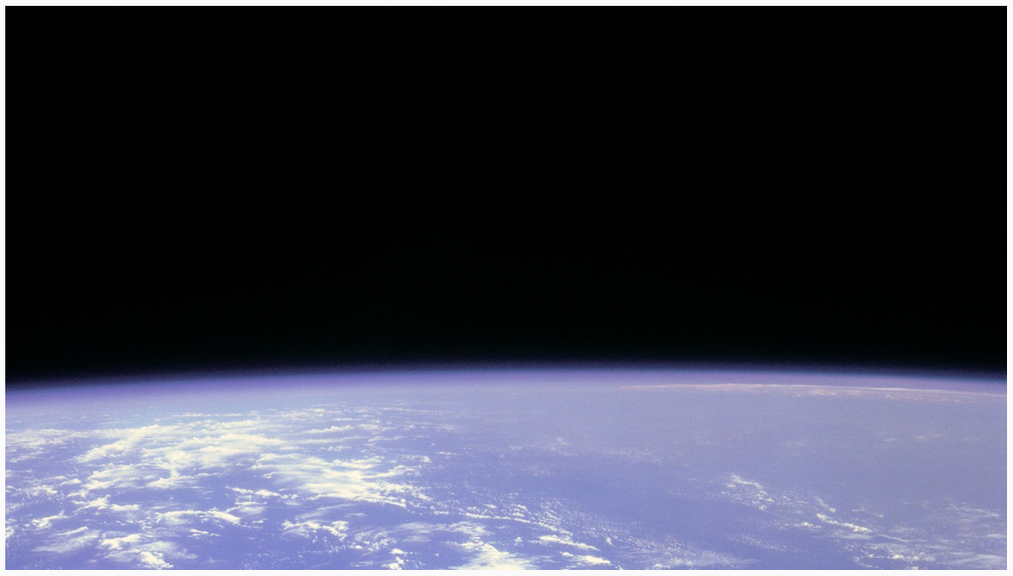
Everything else, black

0.3Kb

Shaved off .7 Kilobytes!

Compression

Everything else, black



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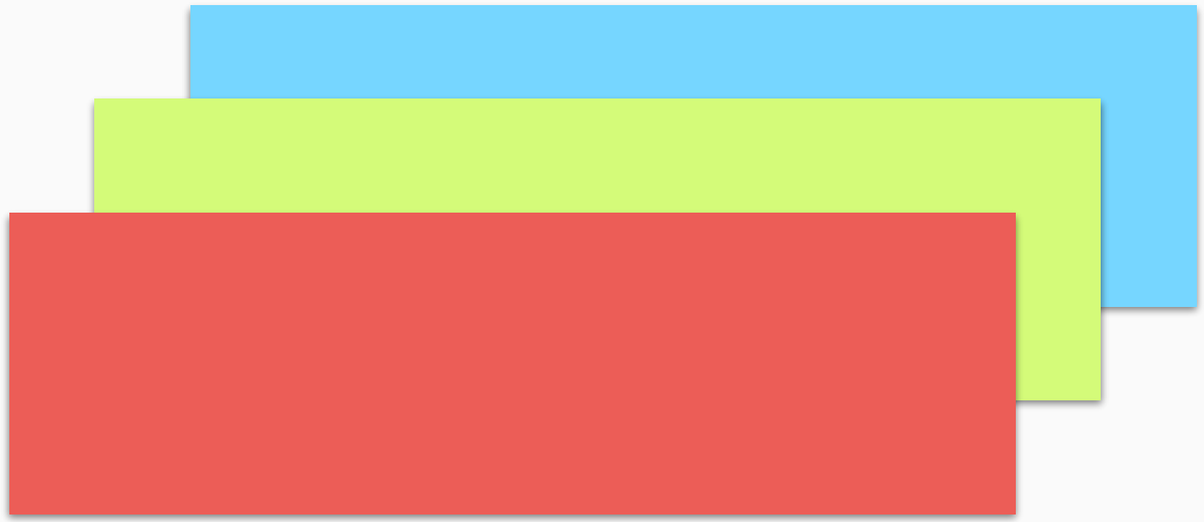

1Kb

0.3Kb

Critical: we can do this with everything

Algorithmic Information

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For a given object…

Q: What is the shortest algorithm that outputs the object we want to describe?

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Let’s consider sequences of english characters…

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Example: Scooooooooooooooooooooooby doo!

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Shaggy's algorithm:
Output "Sc", then 20 "o"'s, then "by doo!"

Algorithmic Information

Q: What is the shortest algorithm that outputs the object we want to describe?

Let's consider sequences of english characters…

Example: aaaaaaaaaaaaaaaaaaaaaaaaa

Shaggy's algorithm:
Output 23 "a"

Problem: Compress Words

- INPUT: A phrase in english
- OUTPUT: A compressed version of that phrase.

Algorithm: Run Length Encoding

- Compress repeated sequences into #repeats, then the letter:
  - E.g. “fooooooooooxesssss!”
    - Becomes: 1f11o1x1e5s
  - E.g. “abbbbbaa zabbbaa”
    - Becomes: 1a5b2a 1z1a3b2a

Clicker Question!

Q: What is, “1W5o1d1e1n 1B3i1r1d1s”, when *uncompressed*?

[A] Woooooden Biiirds

[B] Wooden Birds

[C] Wooden Biiirds

[D] Wooooooden BBBirds

Clicker Answer!

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What Do We Think of This?

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  - E.g. “fooooooooooxesssss!”
    - Becomes: 1f11o1x1e5s
  - E.g. “abbbbbaa zabbbaa”
    - Becomes: 1a5b2a 1z1a3b2a

What Do We Think of This?

- Two drawbacks of note:
  - Q: Are repeated sequences of letters that regular in English?
  - Q: What about numbers?

Algorithmic Information

Q: What is the shortest algorithm that outputs the object we want to describe?

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Q: How *complex* is the object?

Kolmogorov Complexity

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This question ends up being *super fascinating*.

Definition: The length of of this algorithm is called "Kolmogorov Complexity" of the object

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Q: What objects generally have shorter algorithms?

Q: What objects generally have complex algorithms?

Q: Given an object, how can we *find* the shortest algorithm for describing it?

Kolmogorov Complexity

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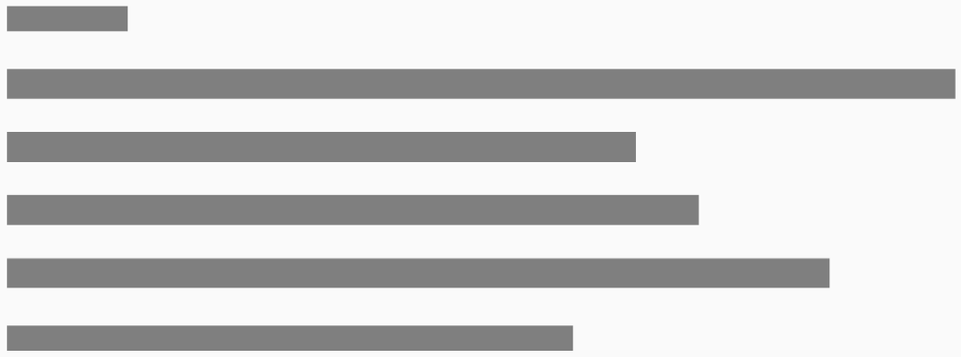
This question ends up being *super fascinating*.

Q: What objects generally have more complex algorithms?



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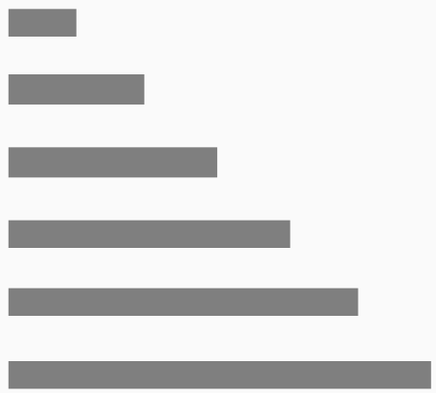
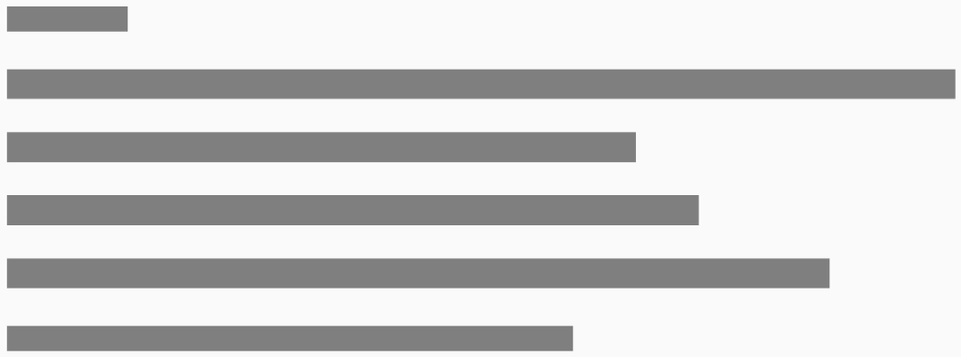
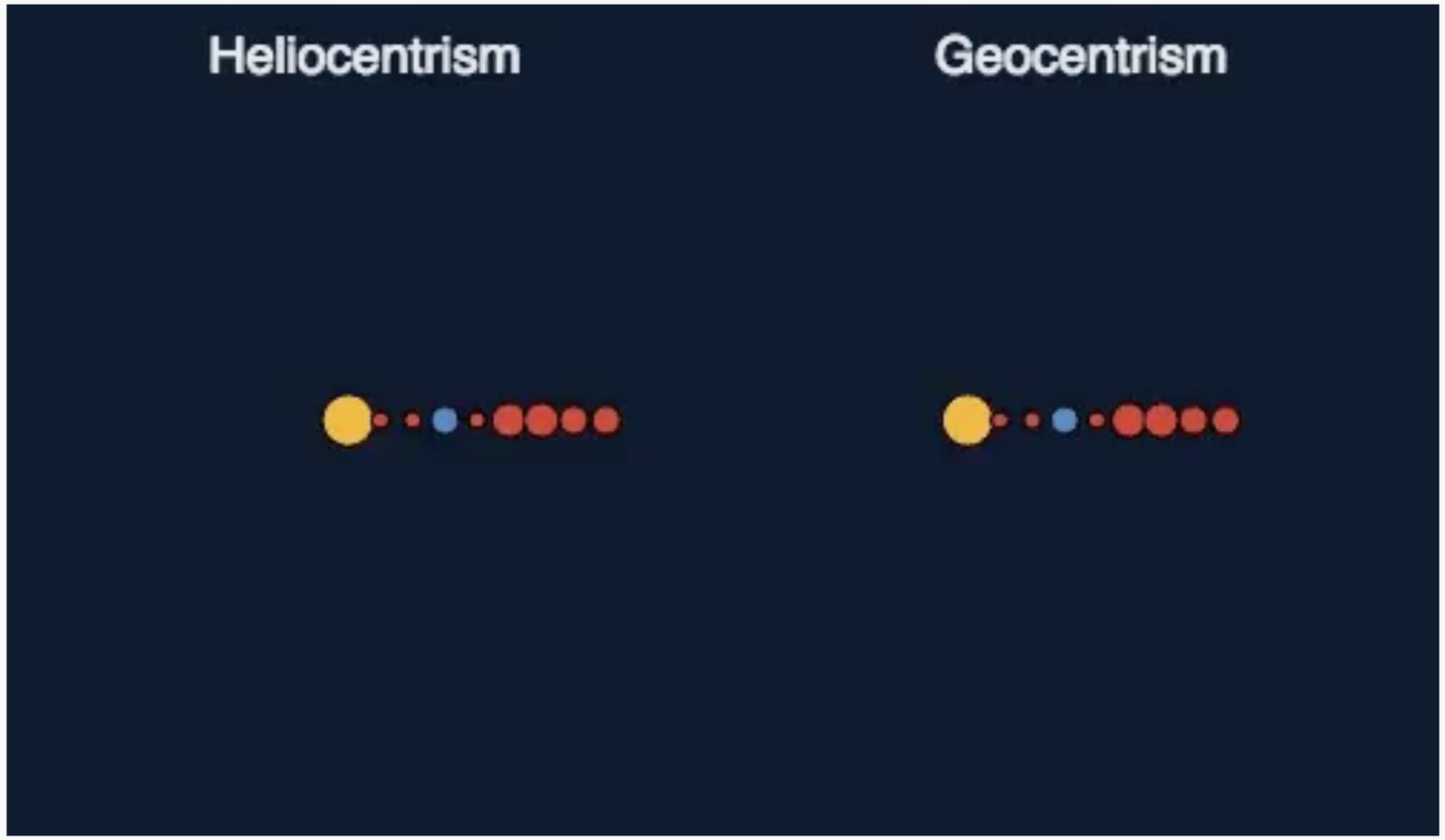




Definition of randomness: *more complicated algorithmic descriptions!*

Kolmogorov Complexity



Definition of randomness: *more complicated algorithmic descriptions!*

Unit 8: Recursion

Dave Abel

April 4th, 2016

Takeaway

Repeated self reference, or “recursion”, is *everywhere*, in the world and in computation! It’s simple, beautiful, and incredibly powerful.

Recursion

- **Definition:** a process, program, or object is said to be *recursive* if it involves repeated self-reference

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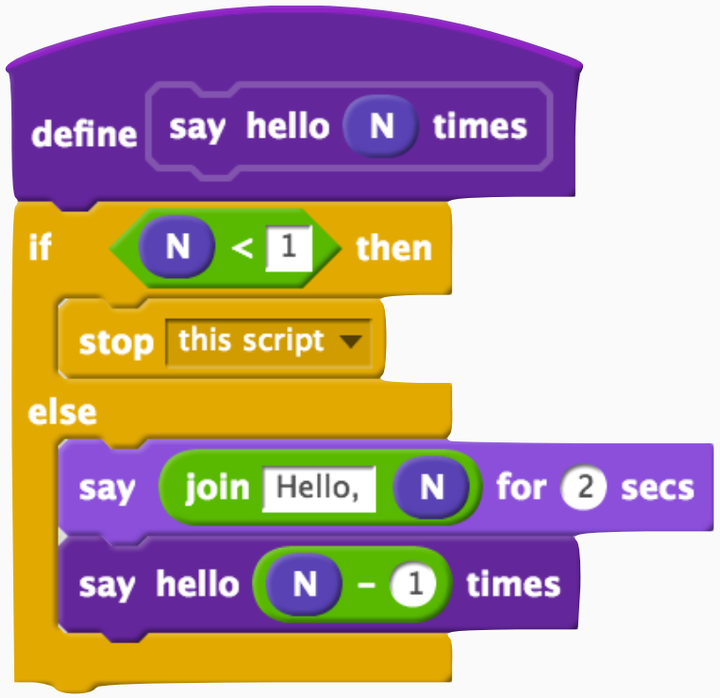
- Example one: **A Scratch block** is recursive if it *calls itself:*



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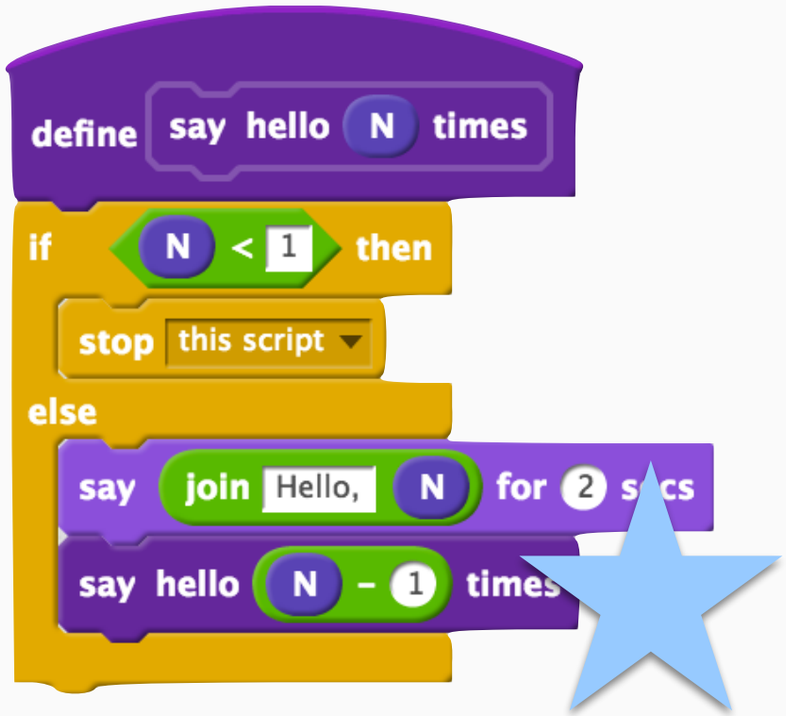

Recursion

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- Example two: a tree!

Recursion

- **Definition:** a process, program, or object is said to be *recursive* if it involves repeated self-reference

- Example two: a tree!

A tree is: a stick, with some number of trees coming off of it.

Recursion

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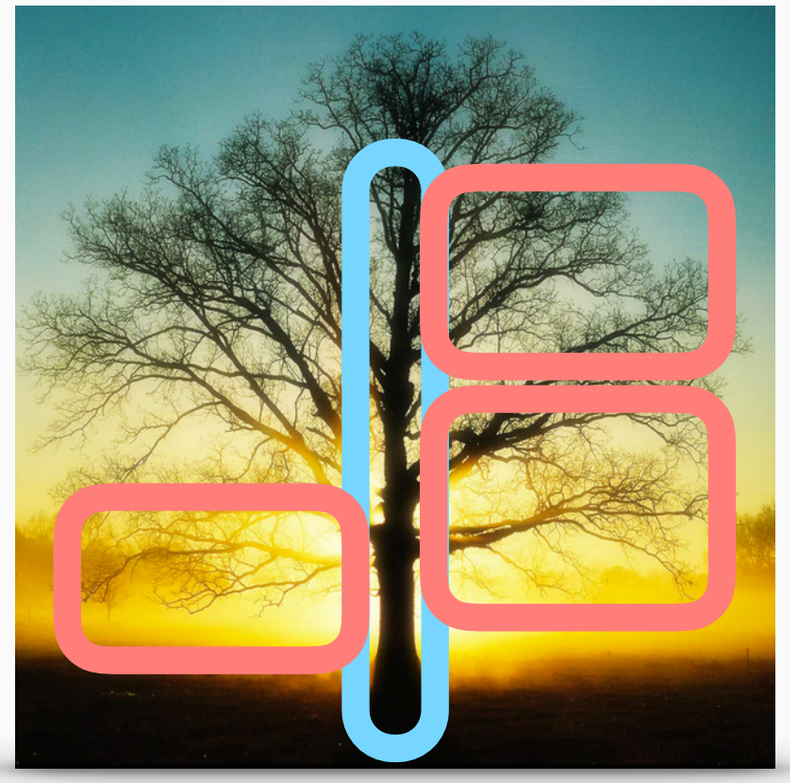
- Example two: a tree!



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Recursion

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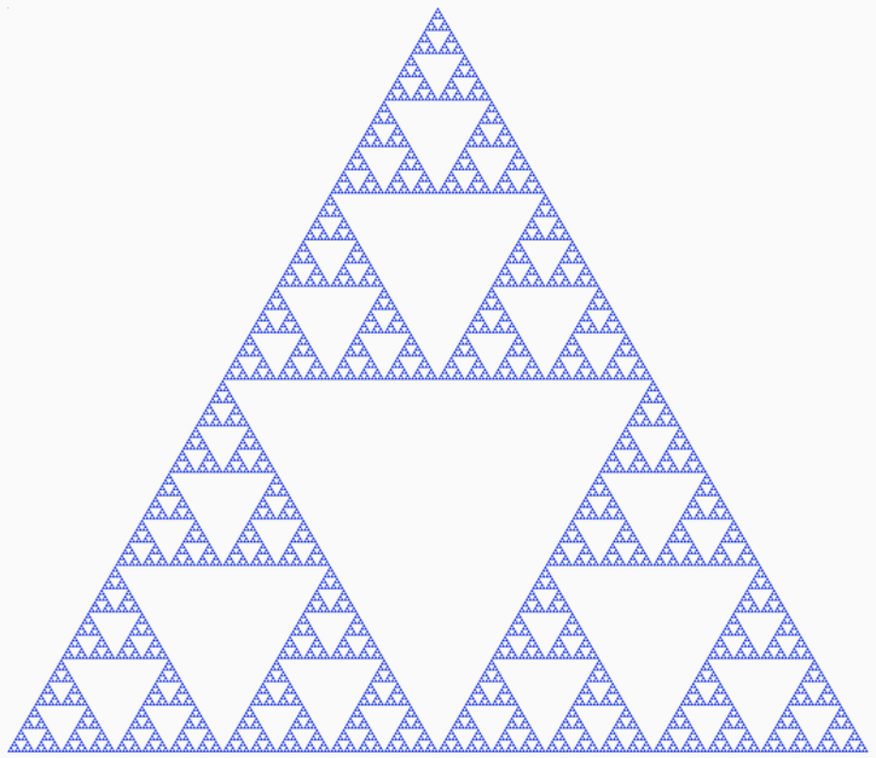
- Example three: **Recursive Shapes!**



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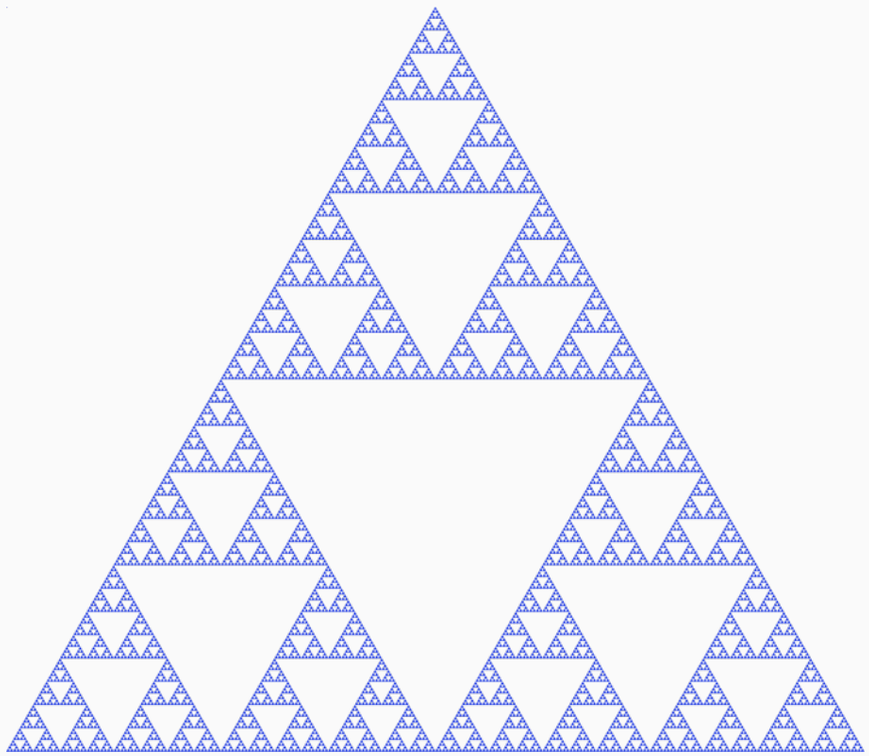
- Example three: **Recursive Shapes!**



A recursive triangle is: a triangle, with a recursive triangle inside of it

Recursion

Discuss with your neighbors and come up with *something* recursive!

Recursion

- **Definition:** a process, program, or object is said to be *recursive* if it involves repeated self-reference

- In general, *recursive entities can be described as:*
  - A simple step
  - A recursive step

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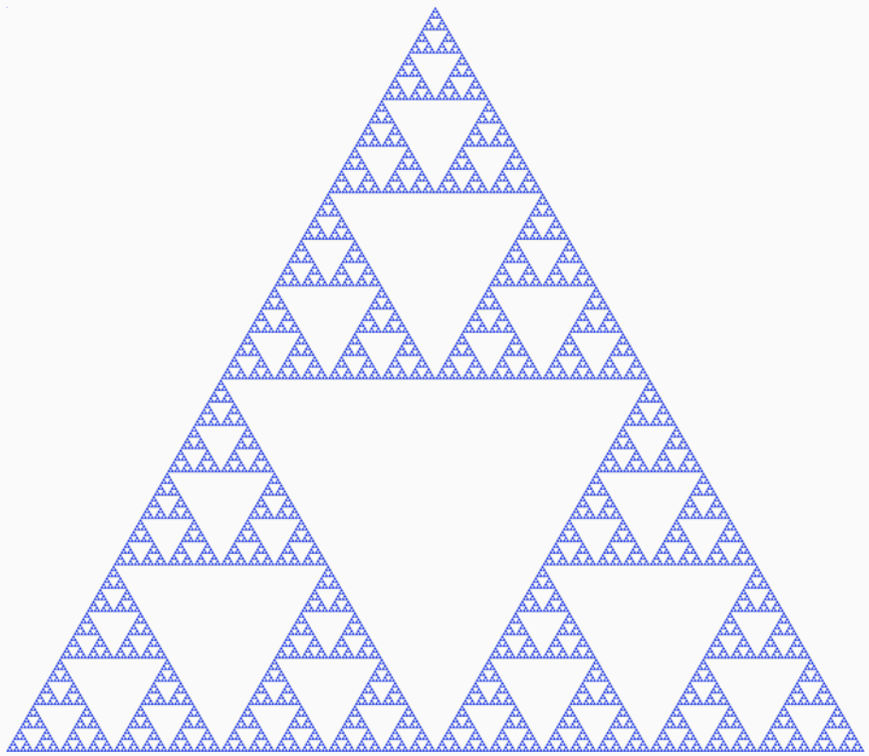
Recursion

- **Definition:** a process, program, or object is said to be *recursive* if it involves repeated self-reference

- Example three: **Recursive Squares!**



A recursive triangle is: a triangle, with a recursive triangle inside of it

Recursion

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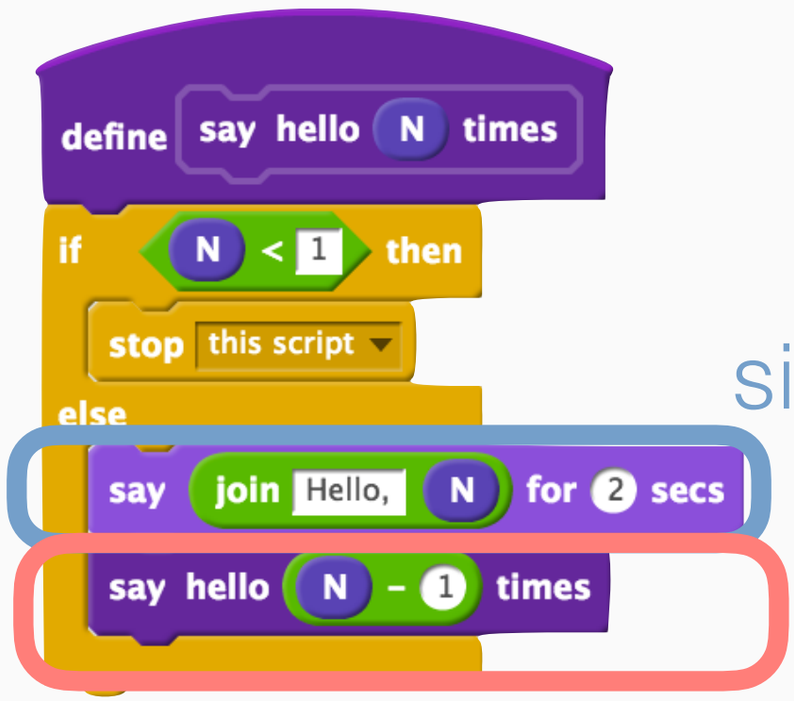
- Example one: **A Scratch block** is recursive if it *calls itself*



Recursion

- **Definition:** a process, program, or object is said to be *recursive* if it involves repeated self-reference
- Many algorithms are *recursive!*
- Let's look at a few.

Recursive Algorithms

- Problem: Is a word a palindrome?
  - *INPUT:* a word
  - *OUTPUT:* True if the word is a palindrome, False otherwise.
- Recursive solution:
  - A word is a palindrome if: the outermost two letters are the same AND the remaining word is a palindrome.

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Recursive Palindrome

- A word is a palindrome if: the outermost two letters are the same AND the remaining word is a palindrome.
  - This basically tells us a solution for solving the problem

Recursive Algorithms

- Problem: Length of a word
  - *INPUT:* A word
  - *OUTPUT:* The length of the word

Brainstorm a recursive solution with your neighbors!

Recursive Algorithms

- Problem: Length of a word
  - *INPUT:* A word
  - *OUTPUT:* The length of the word
- Here's my solution:
  - The length of a word is just 1, plus the length the word you get if you remove one character.

Recursive Algorithms

- Problem: Factorial
  - *INPUT:* A number
  - *OUTPUT:* The *factorial* of that number
  - Example: factorial(4) is 4*3*2*1, factorial(6) is 6*5*4*3*2*1

Brainstorm a recursive solution with your neighbors!

Recursive Algorithms

- Problem: Factorial
  - *INPUT:* A number
  - *OUTPUT:* The *factorial* of that number
- Here's my solution:

Simple step

  - The factorial of a number is just that number times the factorial of one minus that number.

Recursive step

Recursive Algorithms

- One thing that's been swept under the rug!
- Q: When do we *stop* repeating?
- With length of a word, we know to stop at an empty word.
- With factorial, we know to stop because factorial(1) = 1, and nothing after that makes much sense.
- In general, we need to specify *when to terminate*.

Reflection

- Errors happen! So we use codes to make them less destructive to our communicative channels
  - Solution one: repetion
  - Solution two: checksums
- Compression lets us store and send smaller things!
  - Algorithmic Information asks: what is the shortest algorithm that outputs the object we want to describe?
- **Definition:** a process, program, or object is said to be *recursive* if it involves repeated self-reference