



Haym @SalomonCrypto

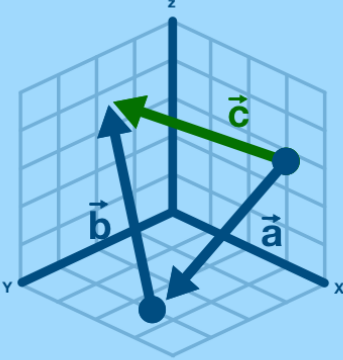
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## (1/8) Computer Science Basics: Vectors

Vectors are a mathematical primitive that turn out to be particularly useful in computer science. In order to understand modern cryptography (and other advanced computational applications), you need a good grasp on this foundational topic.

### Vectors in Computer Science



An arbitrary data set  $(v_0, v_1, v_2, \dots, v_{n-1}, v_n)$  can be expressed as a vector

Vectors can be used in math operations like addition, subtraction, etc.

Vectors can be used to mathematically/programmatically manipulate data in particularly useful ways.

$\vec{a} + \vec{b} = \vec{c}$

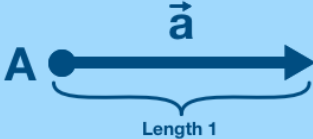
(2/8) A vector is a concept used to convey quantities that cannot be expressed by a single number.

Think about velocity, which is a mathematician's way of saying "speed plus direction."

Speed is 10 m/s. Velocity is 10 m/s in a north-west direction.

## Mathematical Vectors

A vector is used to communicate quantities that cannot be expressed by a single number



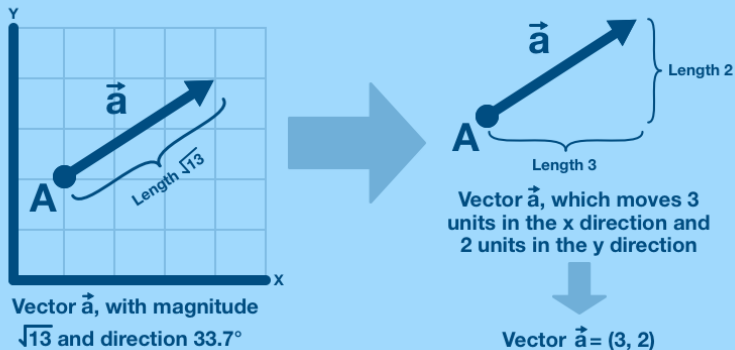
Vector  $\vec{a}$ , with magnitude 1 and direction right

(3/8) Vectors are incredibly versatile and show up again and again across mathematics.

There are many different ways to express a vector, each having their own benefits and drawbacks. Here are just a few of the ways we can express the same information.

## Vector Notation

Vectors can be expressed in many different ways. Each representation is equivalent, but provides different structures that each have useful properties.



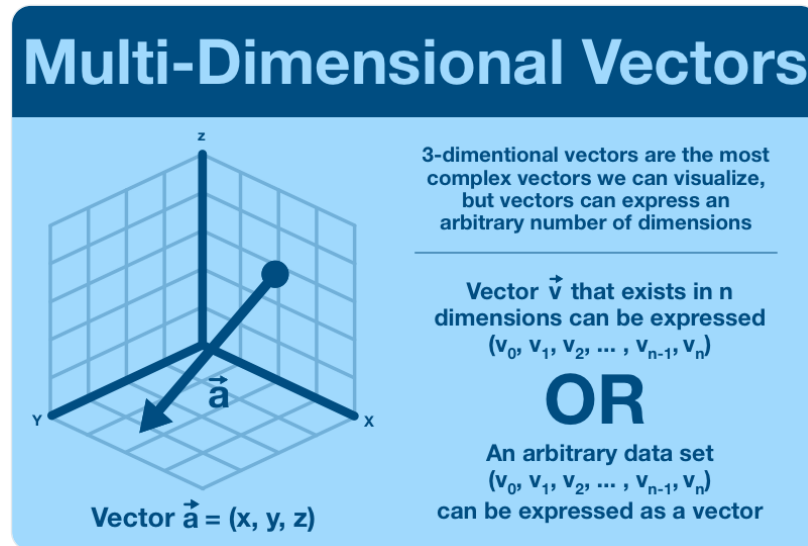
Vector  $\vec{a}$ , with magnitude  $\sqrt{13}$  and direction  $33.7^\circ$

Vector  $\vec{a}$ , which moves 3 units in the x direction and 2 units in the y direction

Vector  $\vec{a} = (3, 2)$

(4/8) First we looked at a single-dimensional vector (tweet 2) and a 2-dimensional (tweet 3). Below is an example of a 3-dimensional vector.

This is as far as the human brain can visualize, but mathematical dimensions can continue far beyond 3; they can go arbitrarily high.



(5/8) A vector in n-dimensional space can hold up to n data points, one piece of data in each dimension.

The easiest way to see this is in the  $(v_0, v_1, \dots, v_n)$  notation. Each dimension provides capacity to store an extra point of data.

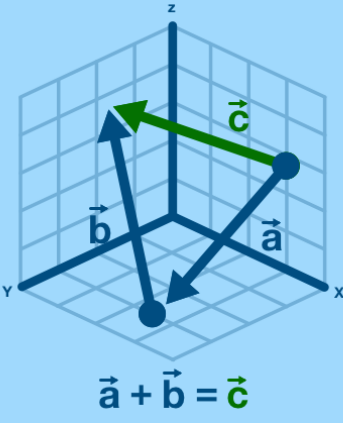
(6/8) Now you might be asking yourself "ok, I understand that we can put data into a vector, but why would I want to?"

Remember, vectors are mathematical primitives. They are incredibly powerful because they can be programmatically manipulated.

(7/8) Think about 3D space, a vector just looks like an arrow.

Take two arrows, place them tip-to-tip. Draw a new arrow from the start of the first one to the end of the second. You've just done vector addition!

## Vectors in Computer Science



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Vectors can be used in math operations like addition, subtraction, etc.

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Vectors can be used to mathematically/programmatically manipulate data in particularly useful ways.

$\vec{a} + \vec{b} = \vec{c}$



(8/8) This is the end of our short intro to vectors.

For now, all you need to remember is simple: vectors allow us to store an arbitrary amount of data in a way that can be mathematically manipulated.

Now let's go look at where we see them in use!

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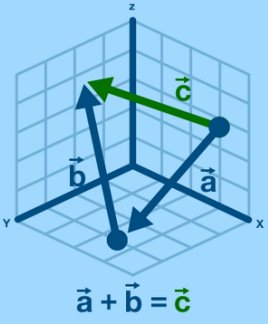
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