TIEA311 Tietokonegrafiikan perusteet
kevät 2019

("Principles of Computer Graphics" – Spring 2019)

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Adapted from: *Wojciech Matusik*, and *Frédo Durand*: 6.837 Computer Graphics. Fall 2012. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu/.

Frontpage of the local course version, held during Spring 2019 at the Faculty of Information technology, University of Jyväskylä: `http://users.jyu.fi/~nieminen/tgp19/`

TIEA311 - Today in Jyväskylä

Plan for today:

- Usual ”what are the feelings now” warm-up in groups of 3. Today sum it up classwide.
- Finalize yesterday’s exercise: only **one more problem** to solve and add to the paper to be hung on your wall. Again: one minute solo, one minute group, classwide correct answer.
- Then, a **sneak preview** or **teaser** of what is to be achieved: Real-world coordinates, points, ”vectors”, normals,
  i.e., the fundamental real-world **objects** that we will be **modeling** in computer graphics.
- Then the major **mathematical tool** for modeling: **Matrices**

Remember from last time: Each and every one of you has now successfully computed an operation between two matrices, using a pen and paper! If not, please attend our previous lecture! (possible with the video technology)

TIEA311 - Today in Jyväskylä

$\rightarrow$ First, finalize yesterday's exercise.

(Like yesterday: One minute solo $\rightarrow$ one minute group $\rightarrow$ classwide correct answer $\rightarrow$ teacher will **try** to surprise you a little bit in the end, with some unexpected information . . .).

Remember this - we will revisit it many times during the course.

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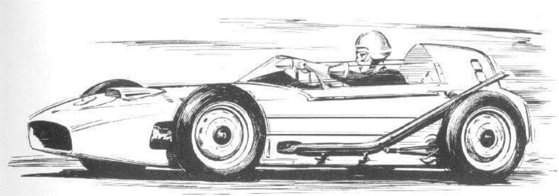
Coordinates and Transformations

MIT ECCS 6.837
Wojciech Matusik

many slides follow Steven Gortler's book

Hierarchical modeling

- **Many coordinate systems:**
  - Camera
  - Static scene
  - car
  - driver
  - arm
  - hand
  - ...

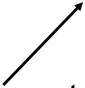


- **Makes it important to understand coordinate systems**

Different objects

- **Points**
  - represent locations

- **Vectors**
  - represent movement, force, displacement from A to B



- **Normals**
  - represent orientation, unit length

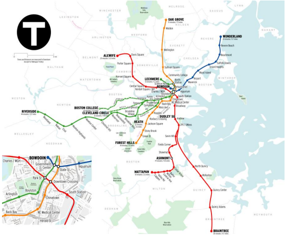
- **Coordinates**
  - numerical representation of the above objects
    in a given coordinate system

$$\begin{pmatrix} 1 \\ 2 \end{pmatrix}$$

Points & vectors are different

- The 0 vector has a fundamental meaning: no movement, no force
- Why would there be a special 0 point?

- It’s meaningful to add vectors, not points
  - Boston location + NYC location =?



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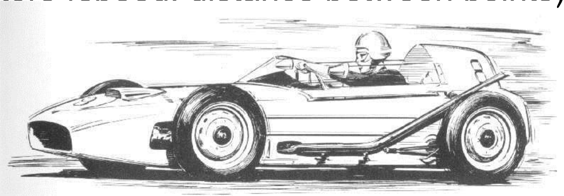
=?

Points & vectors are different

- Moving car
  - points describe location of car elements
  - vectors describe velocity, distance between pairs of points
- If I **translate** the moving car to a different road
  - The points (location) change
  - The vectors (speed, distance between points) don't

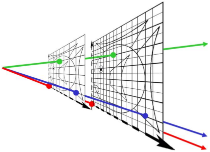


Plan

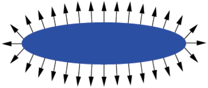
- Vectors

- Points

- Homogeneous coordinates



- Normals (in the next lecture)



TIEA311 - Words of a wiser man

This course is not a math course – far from it!

But we are dealing with “math kinda stuff”, so let me cite Sheldon Axler from his “Preface to the Student” in his wonderful book “Linear Algebra Done Right”:

“You cannot expect to read mathematics the way you read a novel. If you zip through a page in less than an hour, you are probably going too fast. When you encounter the phrase “as you should verify”, you should indeed do the verification, which will usually require some writing on your part. When steps are left out, you need to supply the missing pieces. You should ponder and internalize each definition. For each theorem, you should seek examples to show why each hypothesis is necessary.”

TIEA311 - Words of your teacher

More words about how to read “math-kinda stuff” …

I know that some of you have already taken math or physics courses, so this bit is nothing new to you; yet, please review the material and help me improve it with your own knowledge and understanding.

The Finns can read this (URL valid throughout 2019): `https://tim.jyu.fi/view/users/nieminen/kokeiluja/grafiikan-perusteita`

Others should do a Google search with ”how to read mathematics” and choose a good thing to read. On 16 January 2019, I did the search, Google gave me as first hit `https://www.people.vcu.edu/~dcranston/490/handouts/math-read.html` which I checked and found to be very good. Almost what I wrote in Finnish myself.

TIEA311 - Vector Space of Arrows

Remember that std::vector is just a dynamic array type in C++ STL, not very good for representing real-world vectors as we like to think about them in graphics!

So, what is a ”vector”?

$\rightarrow$ draw some arrows on a plane. Think about possible real-world meanings and applications.

Think about properties of these arrows.

Think about summing and scaling arrows. Meaning?

Think about coordinates. Think about matrices!

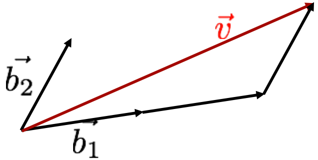
A model for these concrete ”arrow objects”?

Vectors (linear space)

- Formally, a set of elements equipped with addition and scalar multiplication
  - plus other nice properties
- There is a special element, the zero vector
  - no displacement, no force

Vectors (linear space)

- We can use a ***basis*** to produce all the vectors in the space:
  - Given n basis vectors $\vec{b}_i$ any vector $\vec{v}$ can be written as $$\vec{v} = \sum_i c_i \vec{b}_i$$



here:
$$\vec{v} = 2\vec{b}_1 + \vec{b}_2$$

TIEA311 - Matrices

The Finns should read the part about Matrices in this:
`https://tim.jyu.fi/view/users/nieminen/kokeiluja/grafiikan-perusteita`

Others should do a Google search with ”how to compute with matrices” and choose a good read.

Linear algebra notation

$$\vec{v} = c_1\vec{b_1} + c_2\vec{b_2} + c_3\vec{b_3}$$

- can be written as

$$\begin{bmatrix} \vec{b_1} & \vec{b_2} & \vec{b_3} \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix}$$

- Nice because it makes the basis (coordinate system) explicit
- Shorthand:

$$\vec{v} = \vec{\mathbf{b}}^t \mathbf{c}$$

- where bold means triplet, t is transpose

TIEA311 - Matrices

If you have time before next week (I hope you do):

- Read `https://tim.jyu.fi/view/users/nieminen/kokeiluja/grafiikan-perusteita` (non-Finns Google ”how to compute with matrices” and read a good one)
- Compute matrix multiplications with different sized and shaped matrices using pen and paper until there is no doubt that you can do it while asleep!
- Draw arrow vectors, too. + Not only arrow vectors, but their sums and their scaled versions!

Next week:

- We start combining your skills with matrices and vectors to model shapes!