

What is  
computer vision?





**What a person sees**



0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8
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# What a computer sees





**Why are we able to interpret this image?**

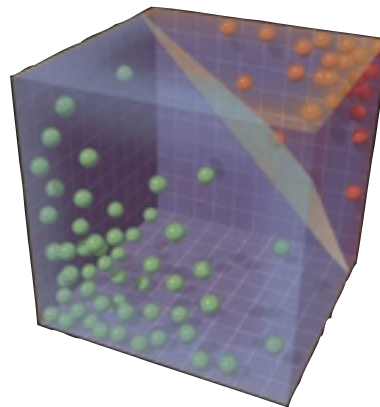


The goal of computer vision is  
to give computers perception



# typical perception pipeline

**representation**



'fancy math'

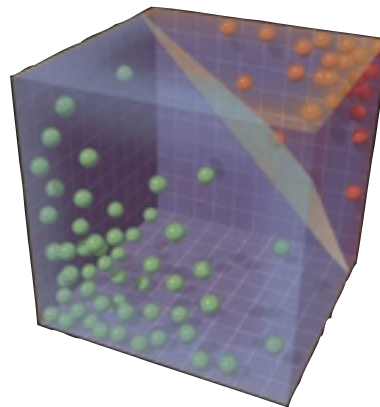


**output**



# typical perception pipeline

**representation**



'fancy math'

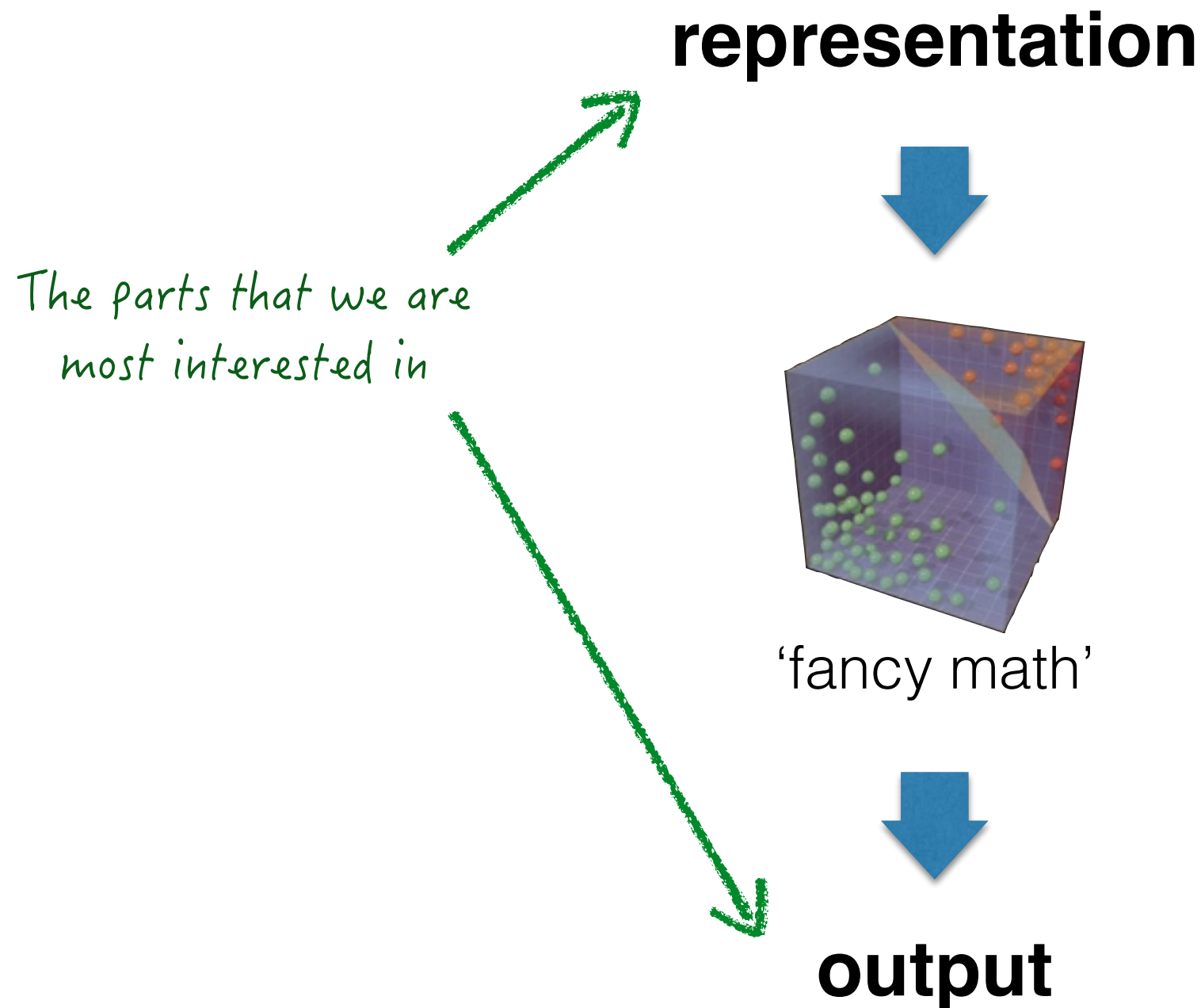
*easy to get lost in the  
techniques*



**output**



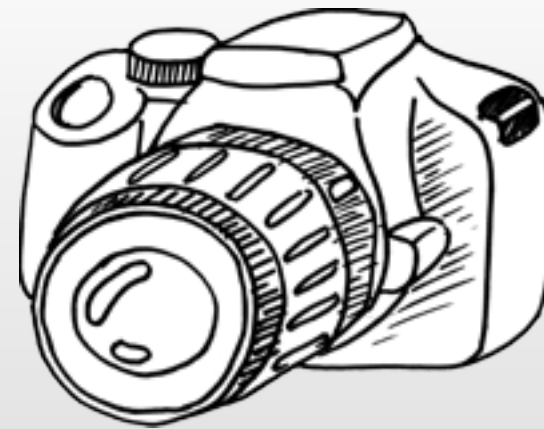
# typical perception pipeline



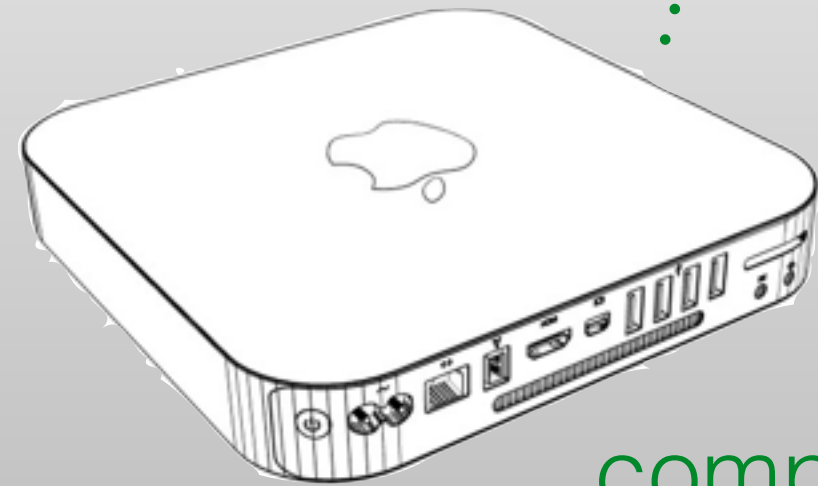
# components of a computer vision system



scene



camera



computer







Applications of computer vision





# Object Recognition



Toshiba Tech IS-910T

2013

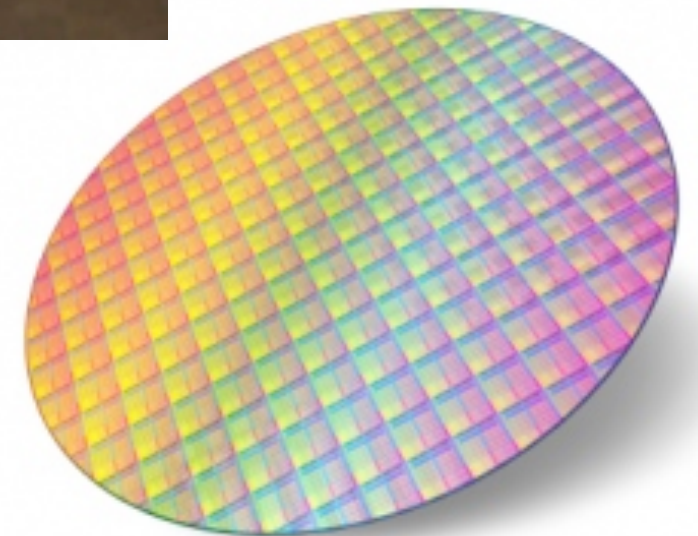


DataLogic LaneHawk LH4000

2012



Automated visual inspection

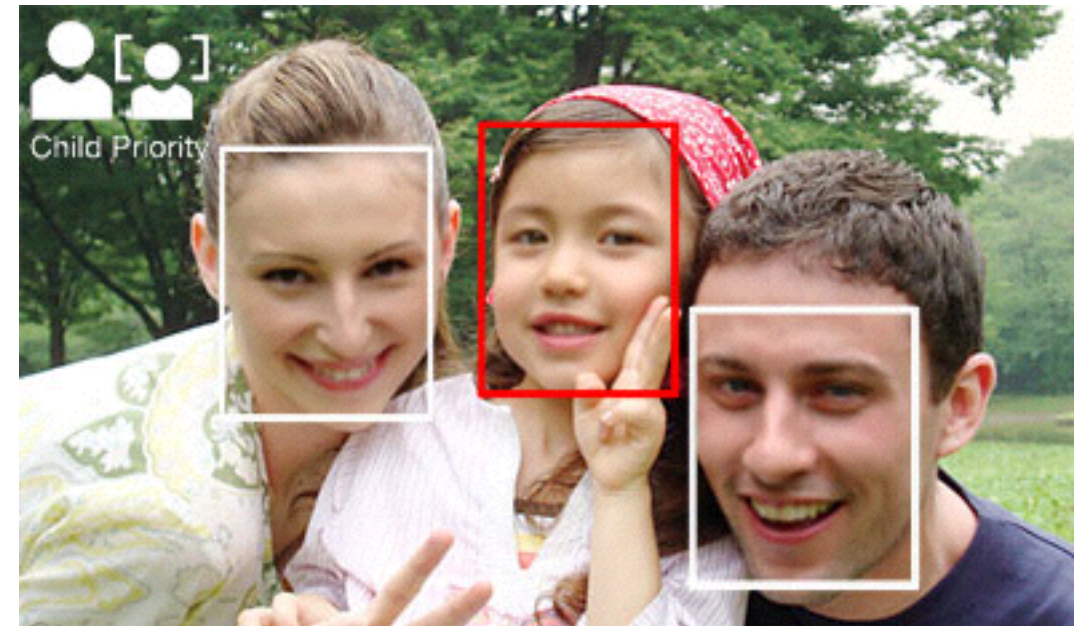




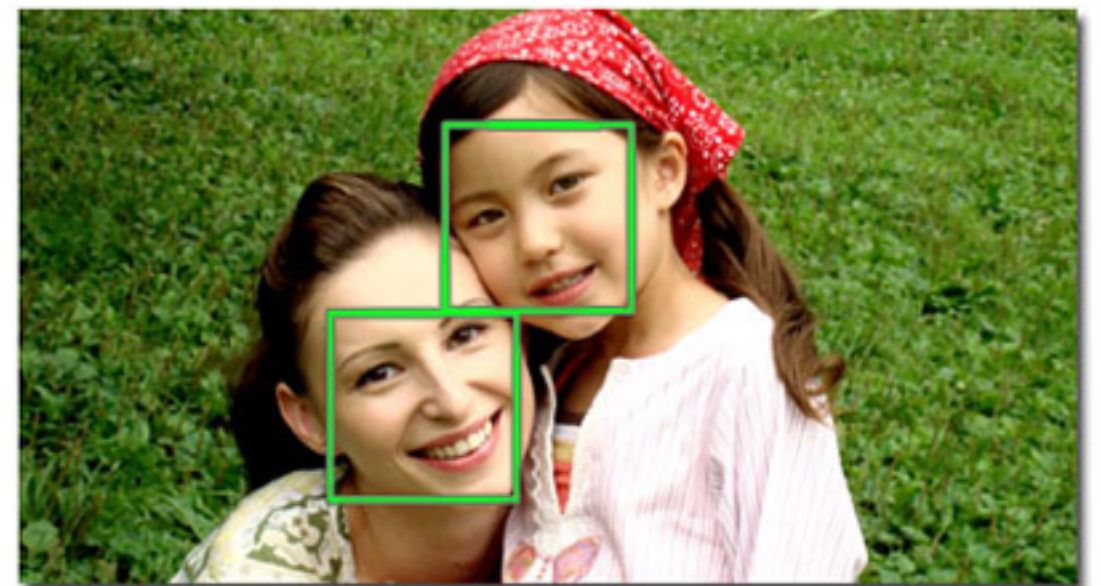
# Face detection



Sony Cyber-shot



Age recognition



Smile recognition





skin filter

eye magnification

eye lash density

ミーハー女子♥3

Y BIJYO COCKTAIL 2

La femme

OH MY GIRL

Bijyo Cocktail

XOXO...♥2





# Face makeovers

**NEW iPhone**  
Hair Try On App

License TAAZ technology  
for web, mobile, in-store

[HOME](#) [START MAKEOVER](#) [BROWSE LOOKS](#) [TRENDS](#) [ADVICE](#) [ABOUT](#)

Creating  
your own  
new look  
is easy

1. upload your photo

2. Apply some makeup

3. Choose a hairstyle

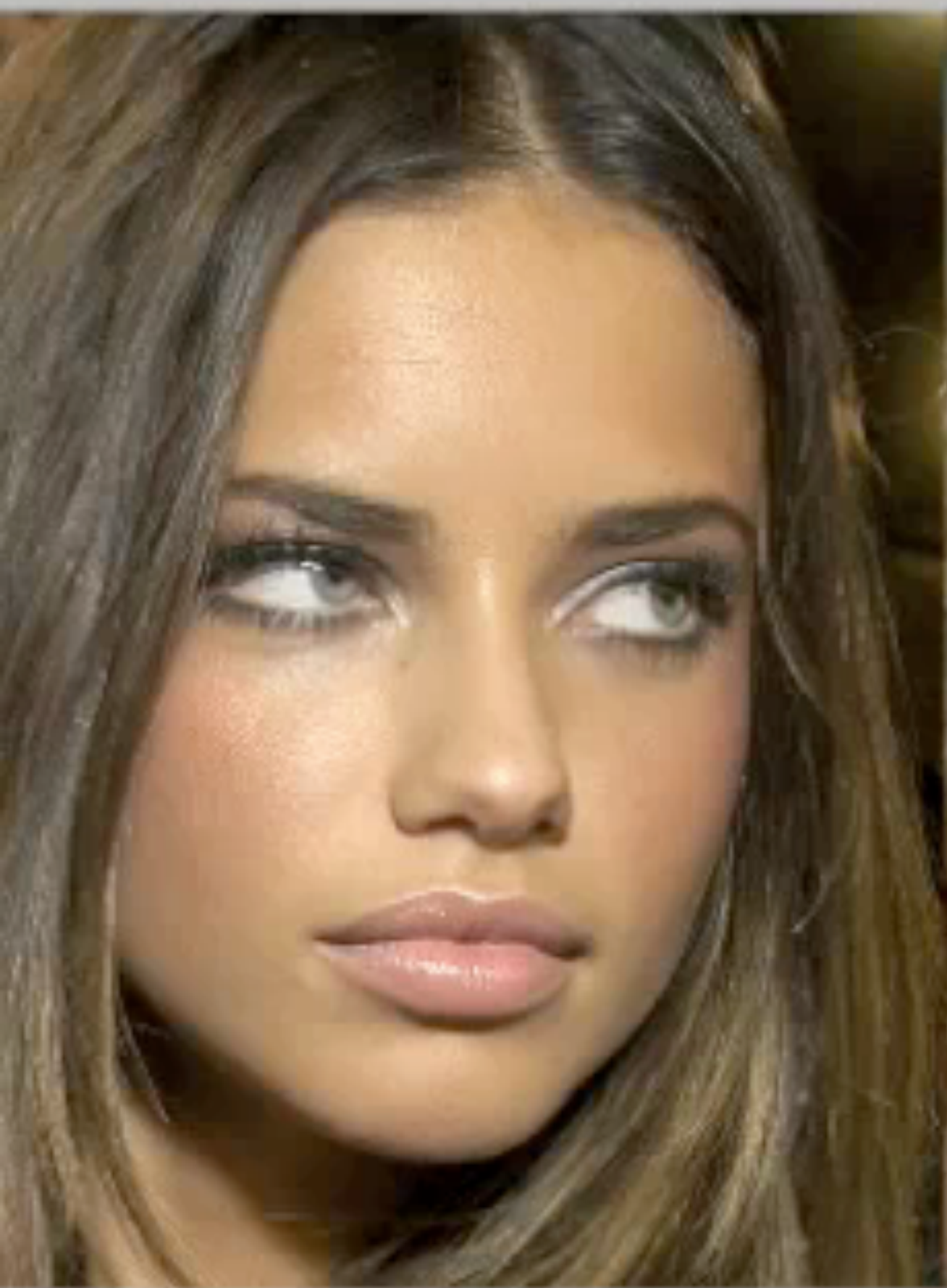
try  
it  
now!

**TODAY'S FEATURED MAKEOVER**  
**rtyjukilop.l,kmujny**  
By: **audreyrose26**  
14 3

Create your own perfect look.  
Try on hairstyles, colors & makeup  
in the TAAZ Virtual Makeover.

**TODAY'S FEATURED ADVICE QUESTION**  
**which look is better?**  
Asked by: **KKsu**  
1 1

Ask your burning beauty question.  
Our community and experts are here  
to help!





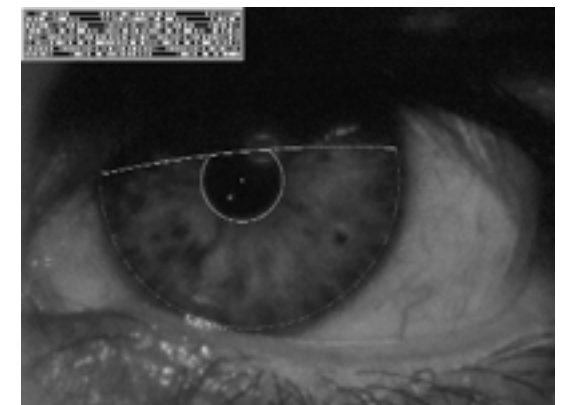
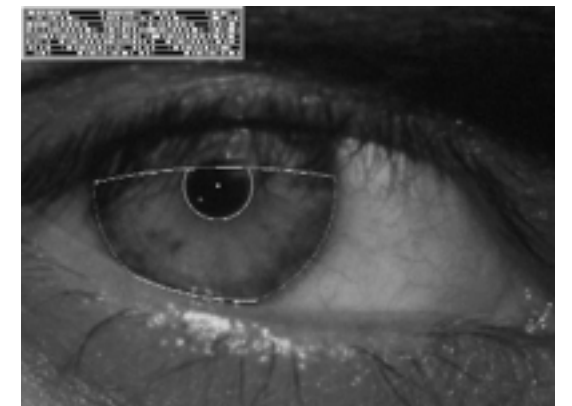
# Forensics



1984



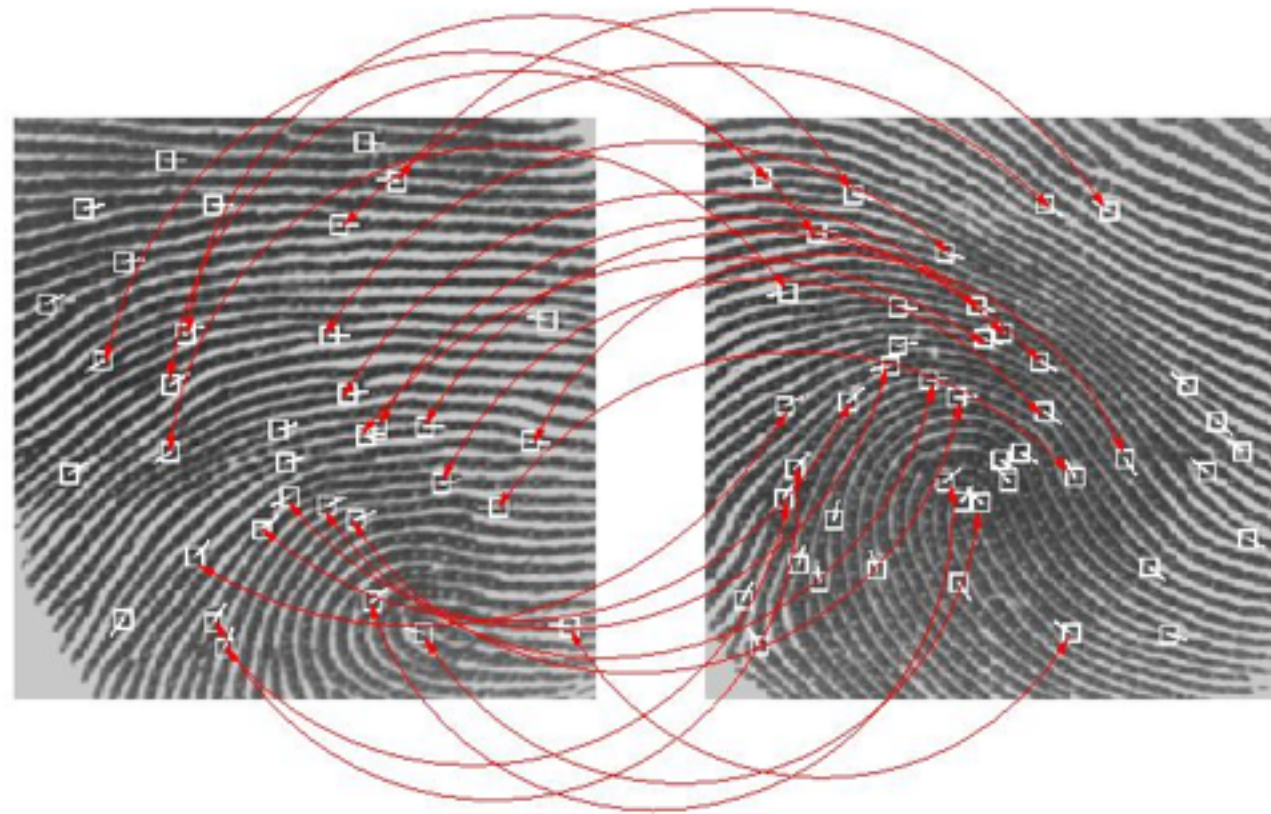
2002



<http://www.cl.cam.ac.uk/~jgd1000/afghan.html>

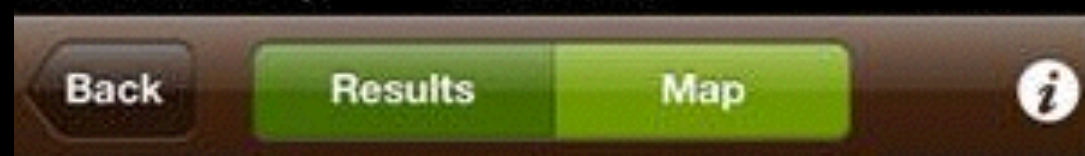


# fingerprint recognition








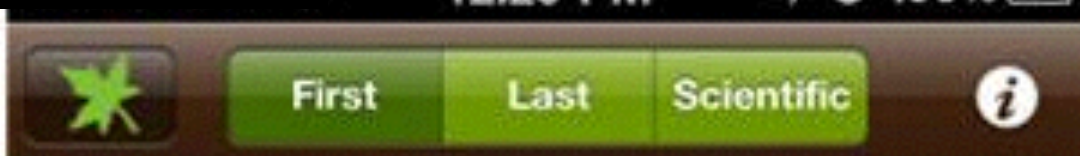
Verizon 12:38 PM



## Snap It! Results

- 1  **Red Maple**  
*Acer rubrum*
- 2  **Striped Maple**  
*Acer pensylvanicum*
- 3  **Sycamore Maple**  
*Acer pseudoplatanus*

12:20 PM 100%



*Ilex opaca*



**American Hornbeam**

*Carpinus caroliniana*



**American Linden**

*Tilia americana*



**American Sycamore**

*Platanus occidentalis*



**Amur Corktree**

*Phellodendron amurense*

Q  
A  
B  
C  
D  
E  
F  
G  
H  
J  
K  
L  
M  
N  
O  
P  
Q  
R  
S  
T  
U  
V  
W  
Y





*leaf* **snap**





**Word Lens**

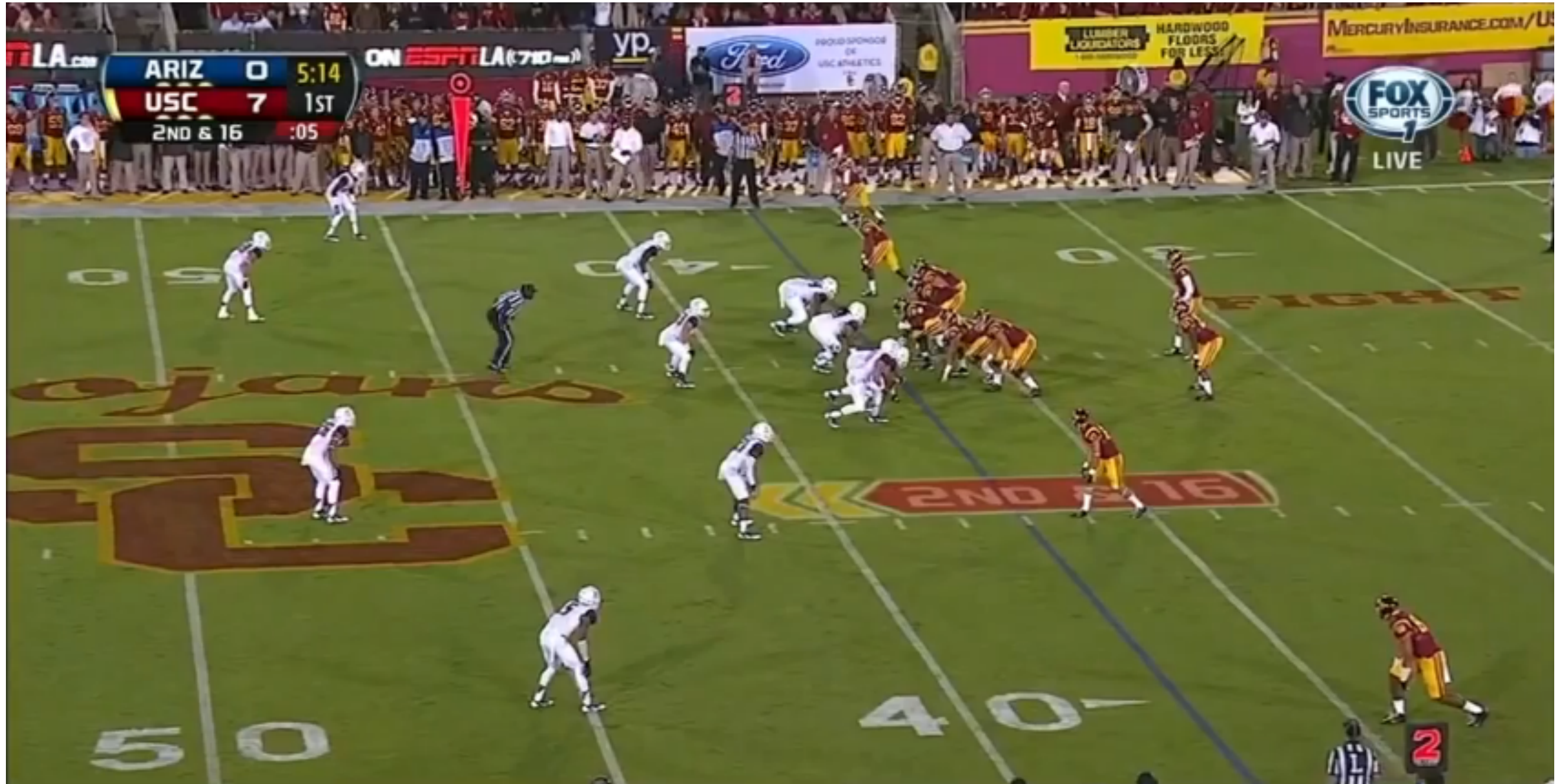


Word Lens

[www.QuestVisual.com](http://www.QuestVisual.com)



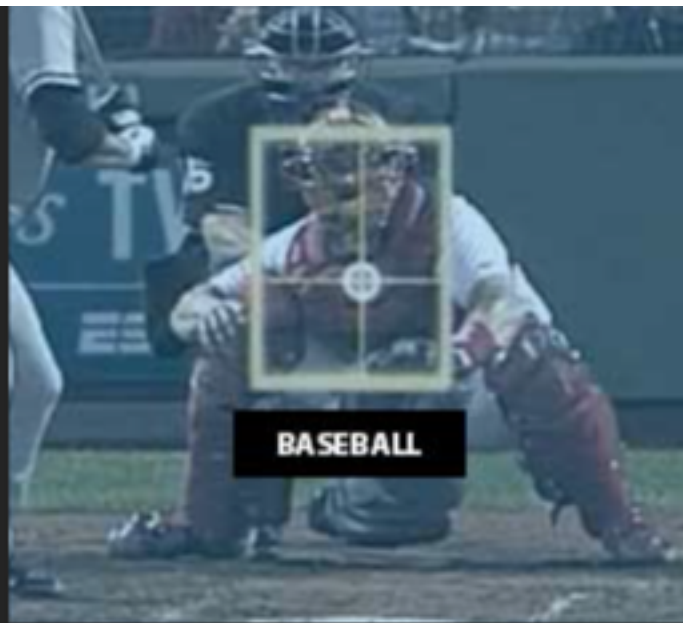
# First-down line



# SportVision



SHOWCASE



BASEBALL



FOOTBALL



MOTORSPORTS



SAILING



OLYMPICS





A man with dark hair and glasses, wearing a dark suit, white shirt, and a patterned tie, is seated at a desk. He is gesturing with his right hand while looking towards the camera. To his right is a large, older CRT computer monitor displaying a webpage with a green header and a small image. The background shows a wall with some papers and a framed picture.

Julius D. Kuetter

Director & Professor, The Wireless Institute  
Carnegie Mellon University

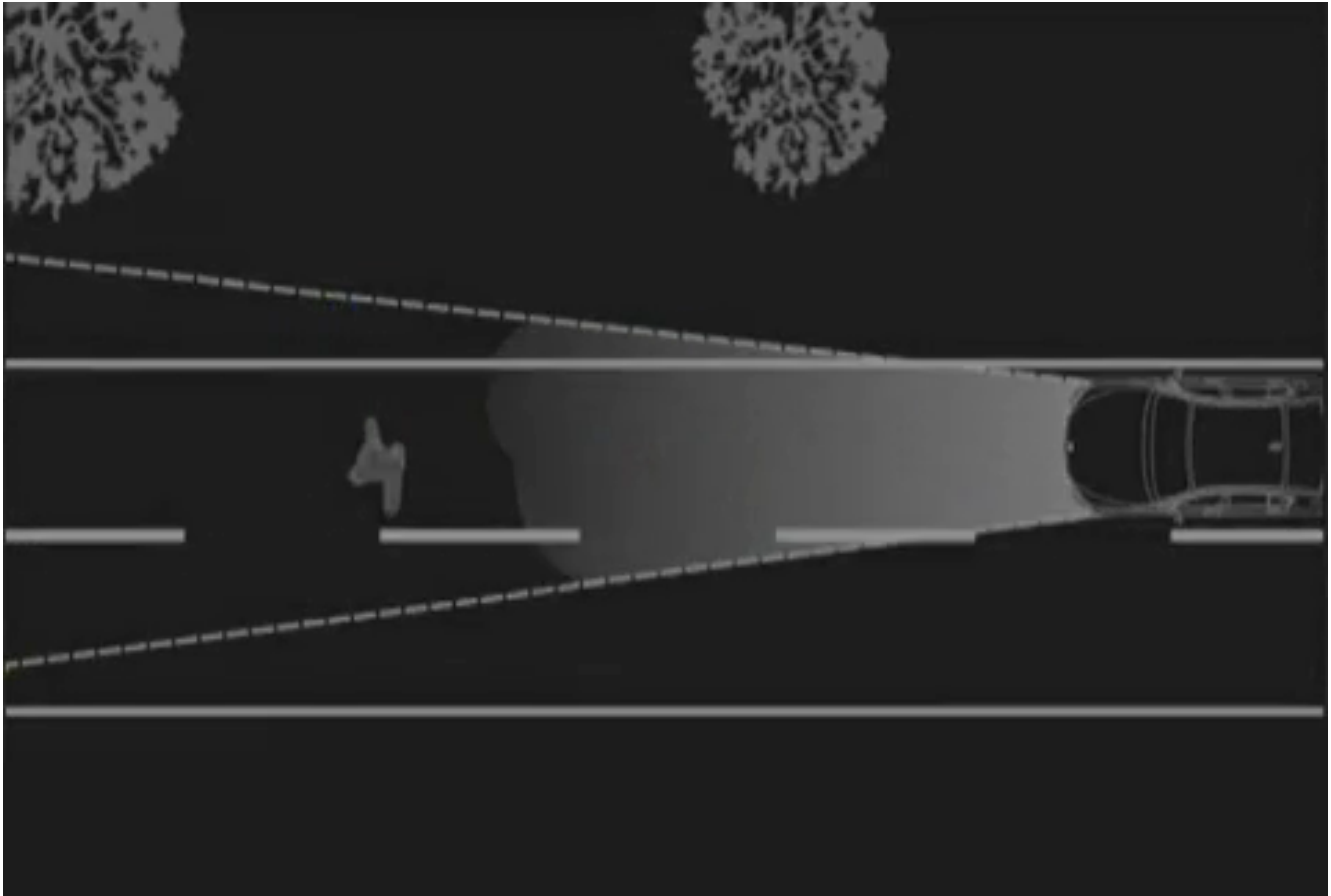




BMW 5 series

BMW night vision









“Around view” camera

Infinity EX





The system converts image data taken by 4 super-wide angle cameras, to display a virtual image of the vehicle from above.



# Image stitching



# Photosynth





# FLUTTER

CONTROL MUSIC & MOVIES WITH GESTURES

1

HOLD YOUR  
HAND TO  
THE WEBCAM

2

WEBCAM  
DETECTS IT

3

FLUTTER  
CONTROLS  
YOUR  
COMPUTER

**DOWNLOAD**  
FOR MAC OS X 10.6+

AVAILABLE ON



MAC APP  
STORE

AND



WINDOWS

ABOUT  
BLOG  
PRIVACY

TWITTER  
FACEBOOK  
PRESS

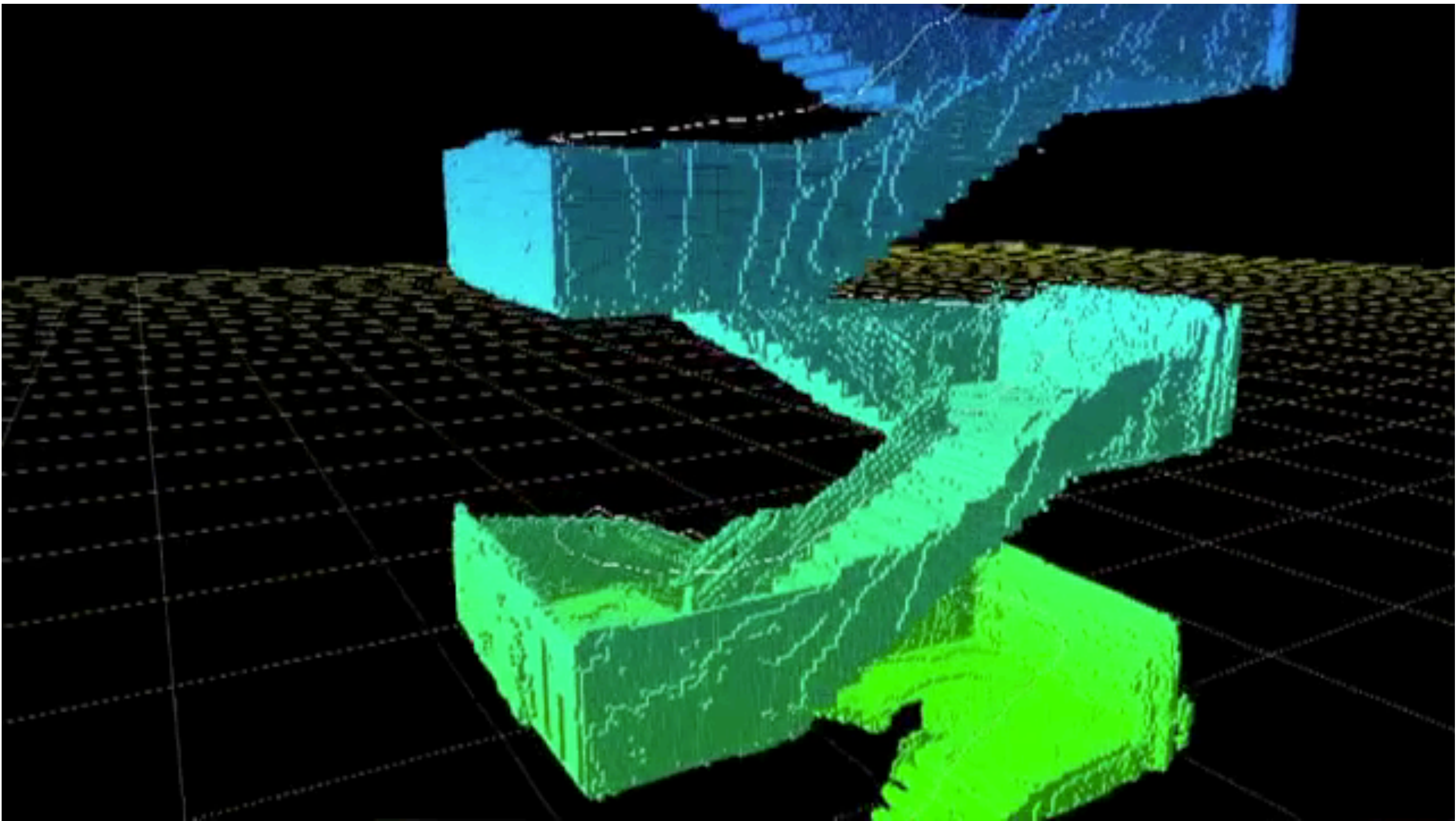
WINDOWS



HAS BEEN ACQUIRED BY Google

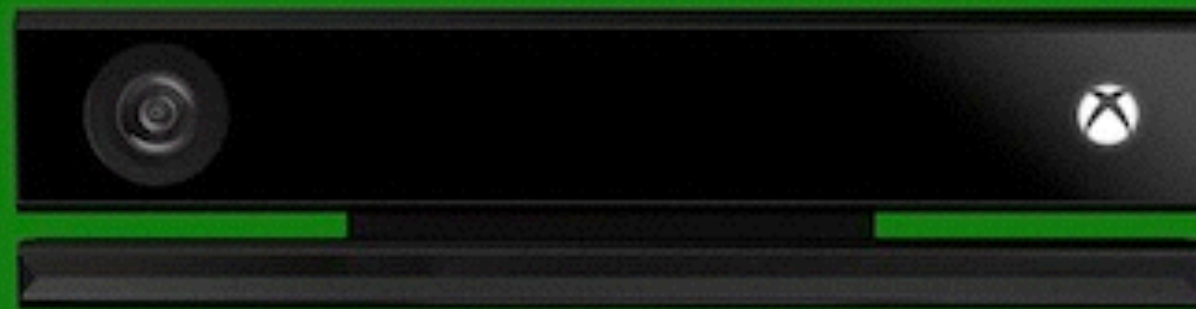








# XBOX ONE



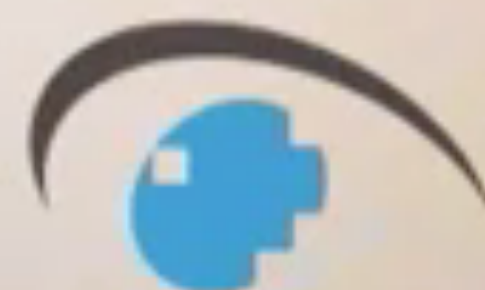
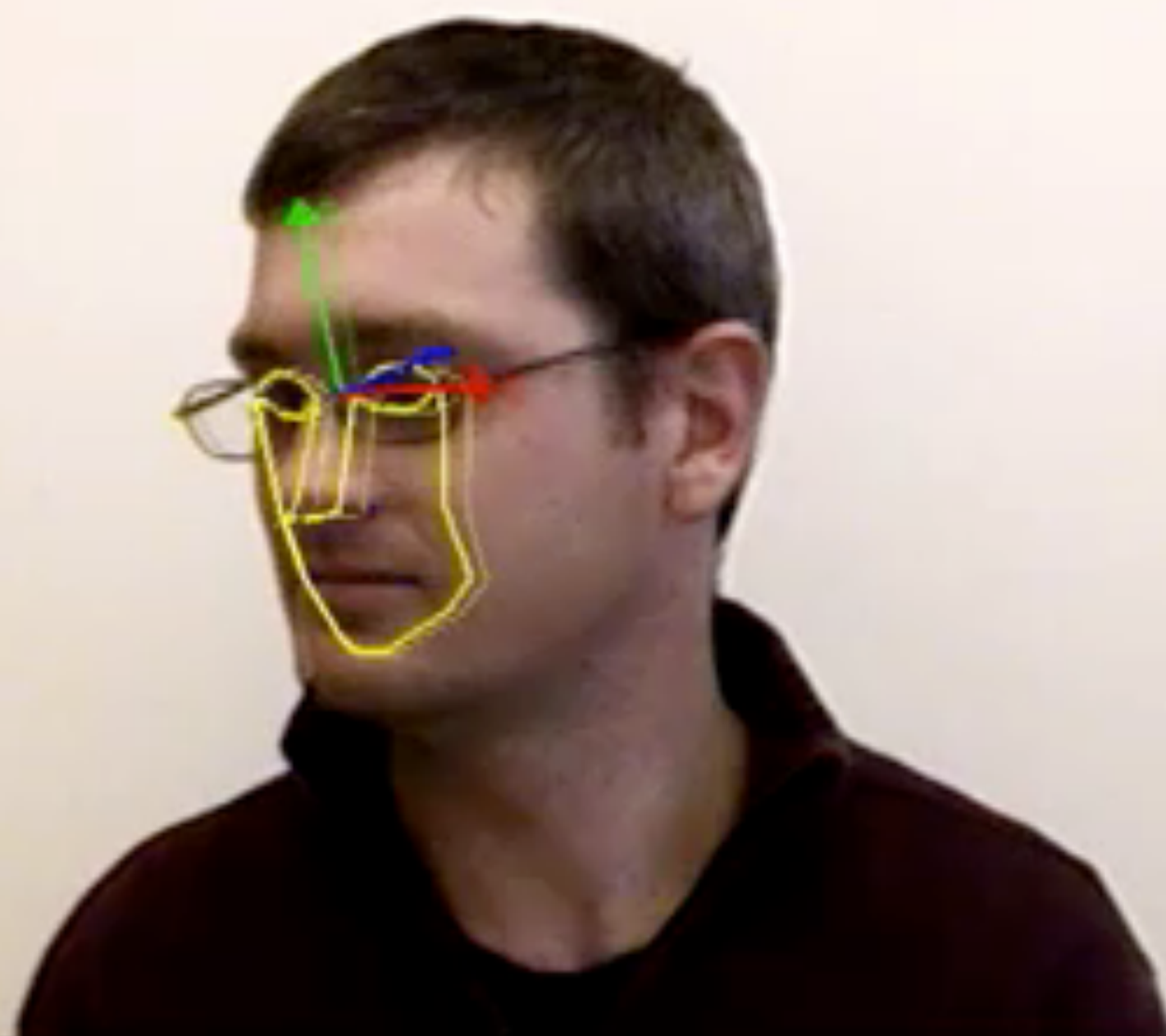




# Augmented Reality







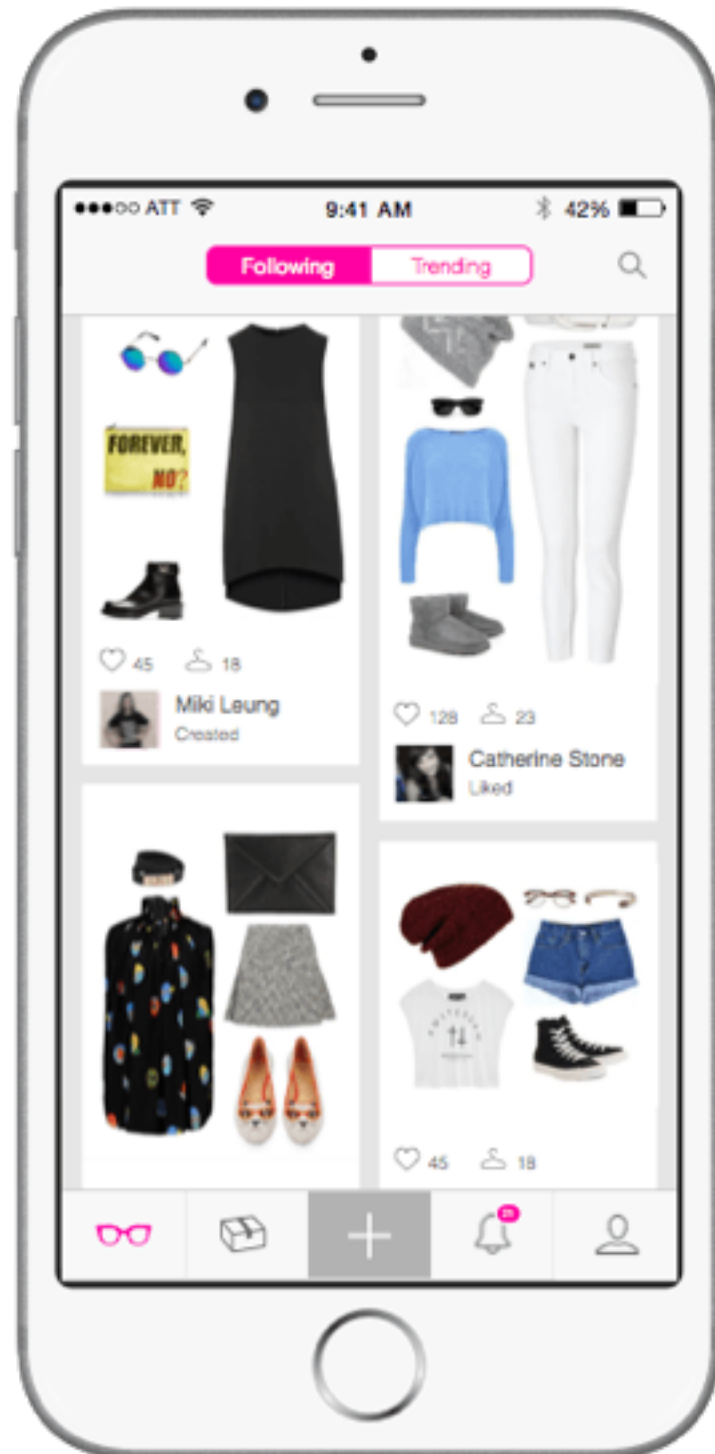
**seeingmachines**  
[www.seeingmachines.com](http://www.seeingmachines.com)

# Virtual Fitting





# STYLE IT



## TEAM



Max  
Fashionista dog



Henry  
Founder



Hua  
Founding member



JG  
Founding member



Sergio  
Founding member



Shawna  
Founding member



Zoe  
Design intern



Lucie  
Fashionista  
evangelist



Tyler  
Marketing intern

CMU alum start up

take a picture of one item

app recommends other clothing  
that go with it

# Computer Vision for VR





2014

# Deep Face



# Vision in Cars



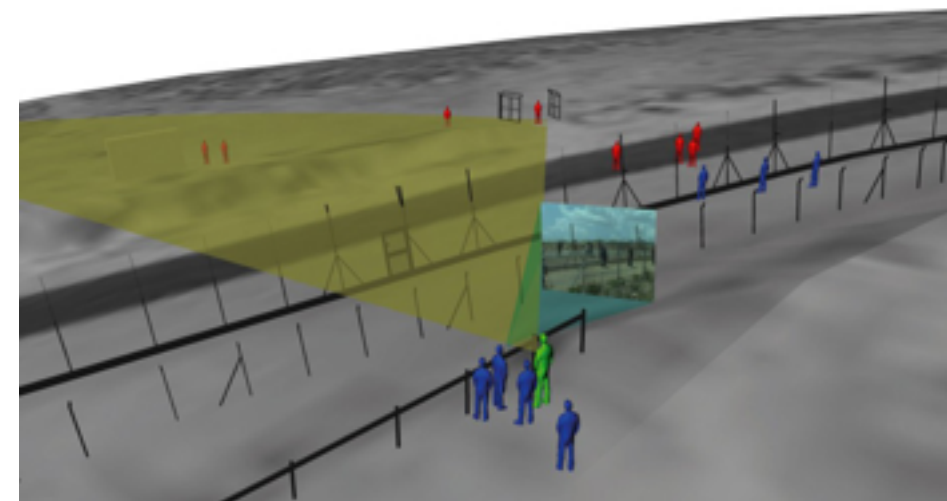


# Social Justice

Human Trafficking



Human Rights  
Video Forensics



# Industry Aggressively Hiring from Universities



**amazon.com**<sup>®</sup>



**Google**<sup>™</sup>

**Dropbox**





**Spring 2015 Carnegie Mellon University**

# **Computer Vision**

16-385

- Lecturer: Kris Kitani
- TAs: Wei-Chiu Ma, Minghuang Ma
- Class: Tuesday, Thursday 12 to 1:20
- Room: NSH 3002

# Website



<http://www.cs.cmu.edu/~16385/>

# Assignments



Blackboard

<https://blackboard.andrew.cmu.edu>

# Discussion&notes

piazza

<https://piazza.com/cmu/spring2015/16385/home>



# Project-based

a lot of programming

hours and hours of programming

days and days of debugging

# Grading

- Projects: 90%
- Mid-term exam: 10%



# Late days

- 3 late days total (not per project)
- use them wisely

## Grading

There are five individual projects and one midterm exam. There is no final exam.

Project 1	Hough Transform	15%
Project 2	Bag of Words	15%
Project 3	Homography	20%
Project 4	Structure from Motion	20%
Project 5	Tracking	20%
Midterm Exam		10%



## Image Processing

<i>Jan 13</i>	Introduction
<i>Jan 15</i>	Filtering
<i>Jan 20</i>	Programming Tutorial
<i>Jan 22</i>	Fourier Analysis
<i>Jan 27</i>	Edge Detection
<i>Jan 29</i>	Hough Transform
<i>Feb 03</i>	Generalized Hough Transform

## Recognition

<i>Feb 05</i>	Feature Detection
<i>Feb 10</i>	Feature Detection
<i>Feb 12</i>	Feature Descriptors
<i>Feb 17</i>	Feature Descriptors
<i>Feb 19</i>	Object Recognition
<i>Feb 24</i>	Bag of Words
<i>Feb 26</i>	Bag of Words
<i>Mar 03</i>	Midterm Review
<i>Mar 05</i>	Midterm Exam
<i>Mar 10</i>	Spring Break; No Class.
<i>Mar 12</i>	Spring Break; No Class.

## **Image Transformations(2D)**

<i>Mar 17</i>	2D Transforms
<i>Mar 19</i>	2D Alignment, RANSAC

## **Multi-view Geometry(3D)**

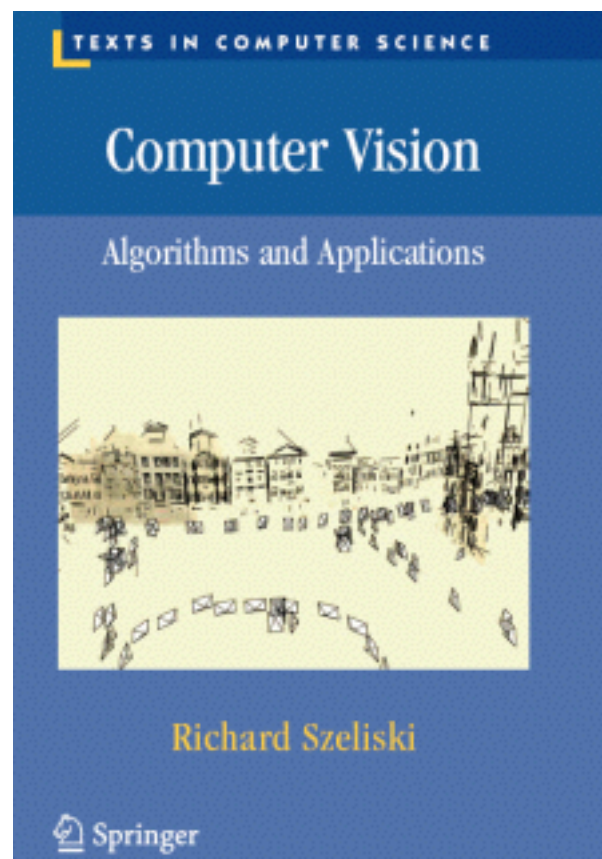
<i>Mar 24</i>	Pose Estimation, Triangularization
<i>Mar 26</i>	Epipolar Geometry
<i>Mar 31</i>	Essential and Fundamental Matrix, 8 Point Algorithm
<i>Apr 02</i>	Reconstruction, Stereo Vision
<i>Apr 07</i>	Applications of N-view Geometry

## **Video Analysis**

<i>Apr 09</i>	Optical Flow(Horn-Schunck)
<i>Apr 14</i>	Image Registration(Lucas-Kanade)
<i>Apr 16</i>	No Class.
<i>Apr 21</i>	Image Registration(Lucas-Kanade)
<i>Apr 23</i>	KLT Tracking
<i>Apr 28</i>	Mean-shift Tracking
<i>Apr 30</i>	Guest Lecture

# Book

(optional)



PDF online

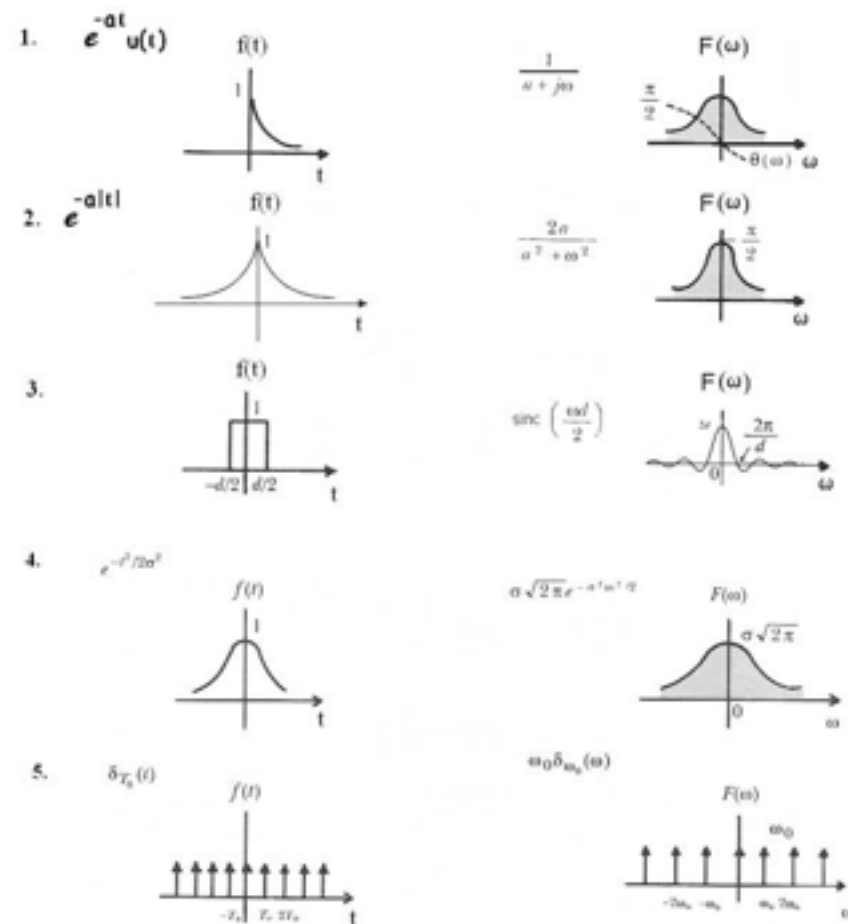
<http://szeliski.org/Book/>



No screens  
(smartphone, tablet, laptop, etc.)  
\*unless for taking notes

# Class Overview

# Image processing



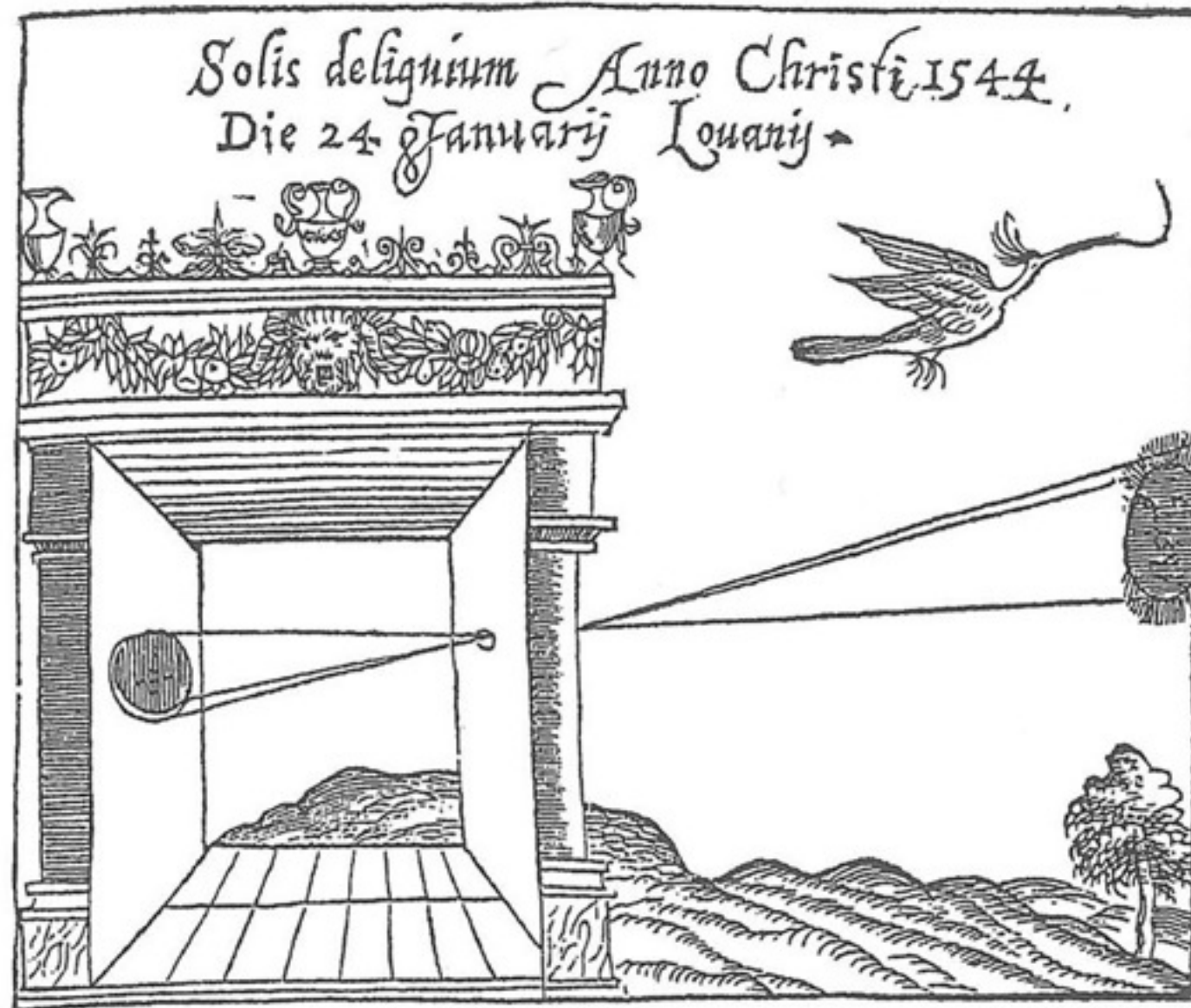
Fourier Transform  
Sampling, Convolution



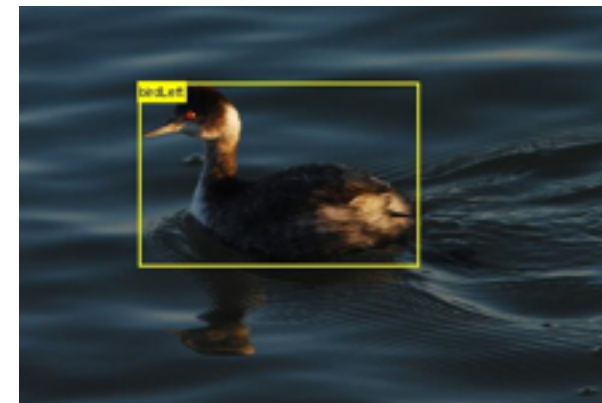
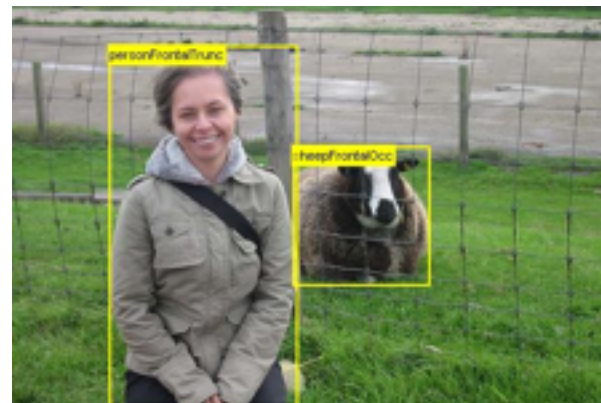
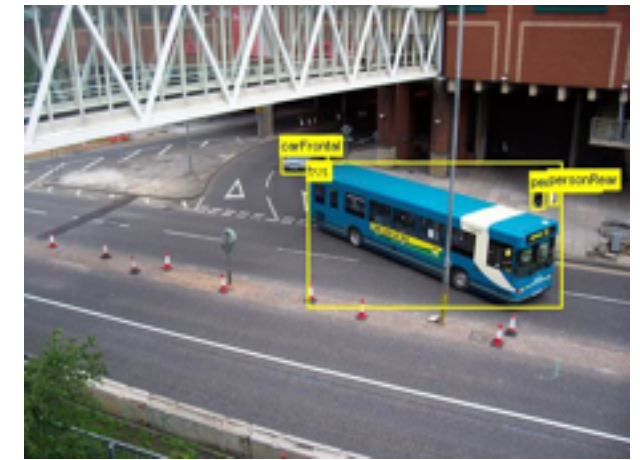
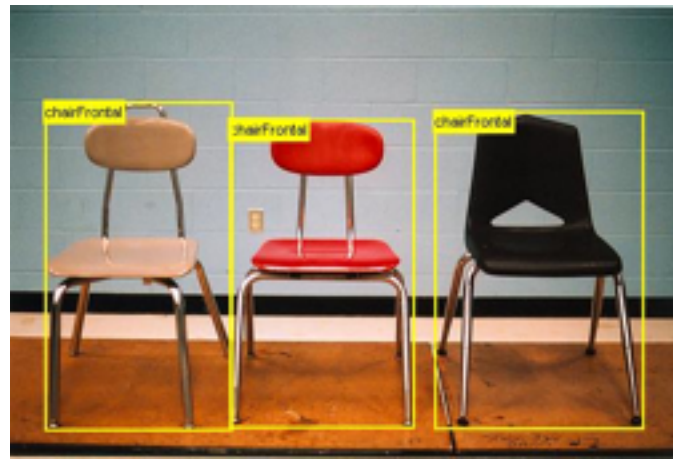
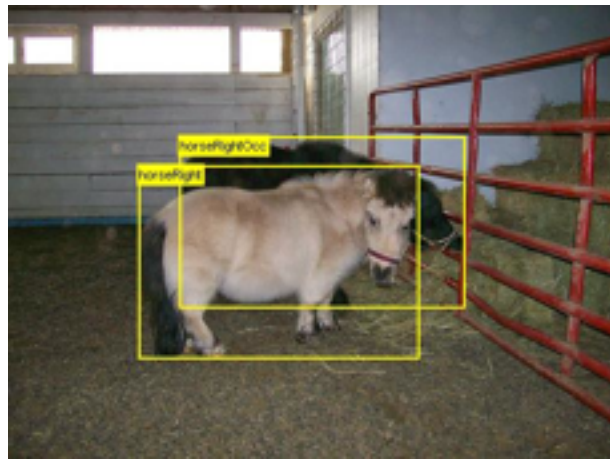
Image enhancement  
Feature detection



# Camera optics



# Object detection



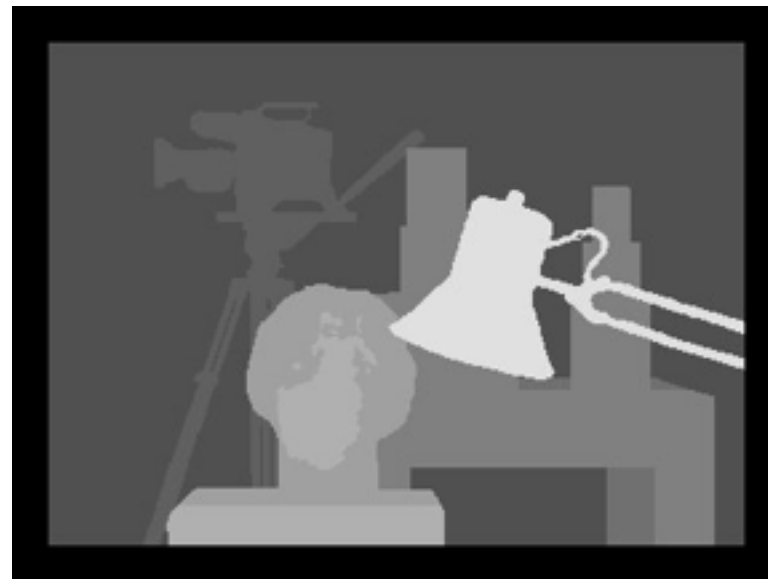


# Image mosaicing

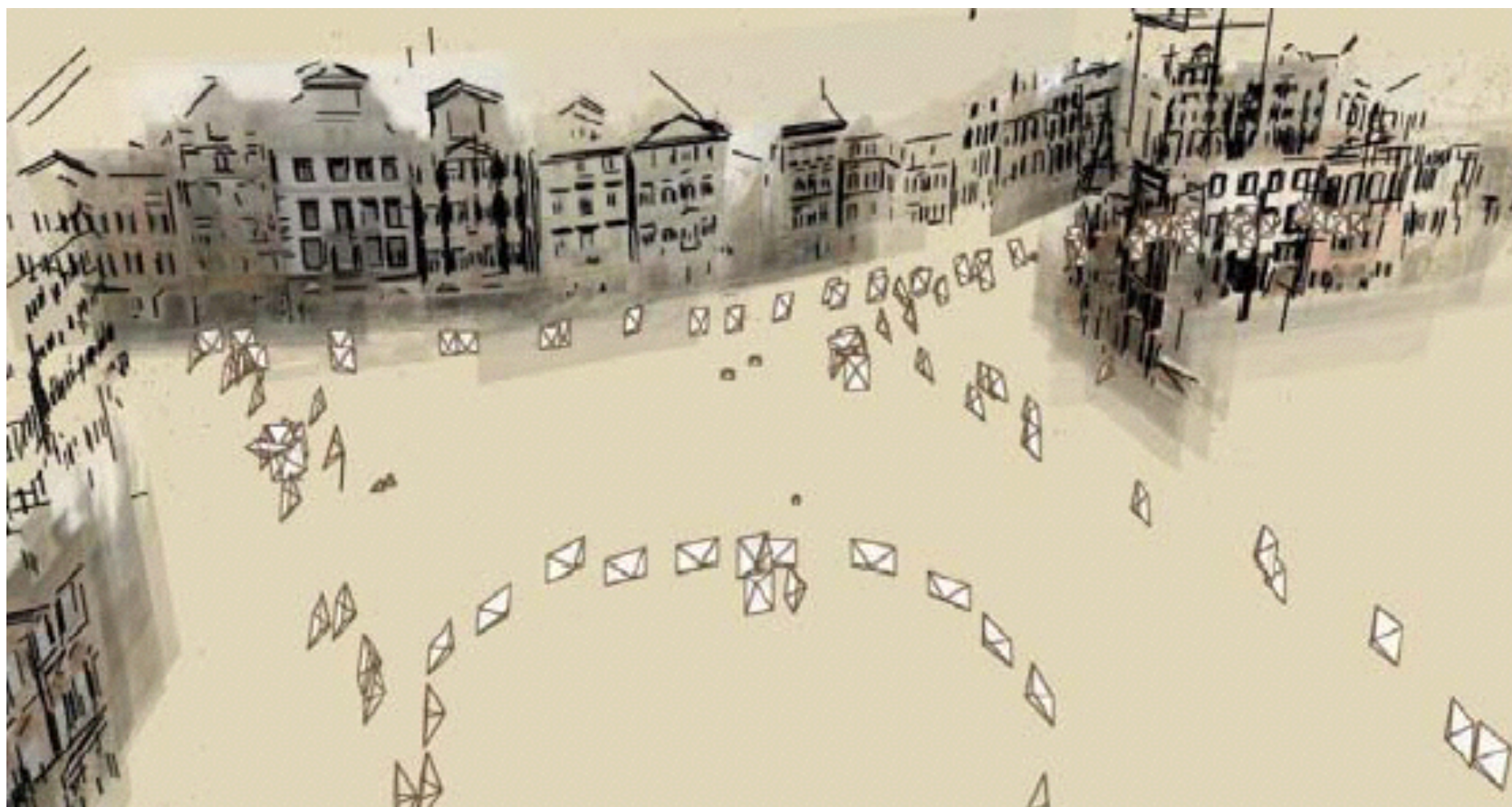




# Binocular Stereo



# Structure from Motion





# Optical Flow





# Tracking

