00:07

okay so

00:09

today

00:12

i'm going to talk about

00:15

computer graphics

00:17

which is actually located in the chapter

00:19

10

00:20

of the textbook

00:23

we have a computer graphics course

00:25

named

00:28

encoded as

00:30

csc

00:31

csc 461

00:38

hit the fourth year selective

00:40

course

00:42

uh

00:44

today in the in this lecture i'm going

00:46

to talk about

00:47

the scope of computer graphic graphics

00:49

what computer graphics is

00:51

what is 3d 3d

00:53

operations what is modeling and

00:55

rendering

00:57

ray tracing scan line rendering

01:00

what are the lighting equations and how

01:02

the animation computer animation is done

01:07

also there are 2d versus 3d graphics for

01:10

example this is a

01:13

2d graphics

01:15

right

01:16

a triangle is a 2d graphics

01:19

on the other hand

01:20

when you have

01:22

a box image

01:25

it is considered as a 3d graphics

01:27

because the model is

01:31

the model is 3d

01:33

actually the image is 2d

01:35

my screen is 2-dimensional so the

01:38

so the image is two-dimensional

01:47

can you close the door

01:55

so this is this triangle is

02:06

last person should close the door

02:13

he doesn't know it so you should do it

02:15

he doesn't know it

02:20

same thing that i talked at the

02:22

beginning of the course if if there are

02:24

too many people in the on the street and

02:25

one person is dying nobody cares

02:32

so

02:33

we got no problem

02:34

so

02:36

we will we will be talking about

02:38

computer graphics for the rest of the

02:40

day

02:43

let me introduce two-dimensional

02:45

graphics and three-dimensional graphics

02:47

again on a two-dimensional screen this

02:49

is a two-dimensional screen there is an

02:51

x and y

02:52

but i can display

02:54

three-dimensional objects or

02:55

two-dimensional objects in

02:56

three-dimensional objects

02:59

we call it three-dimensional graphics 3d

03:02

graphics actually the screen is two

03:04

dimensional

03:06

but yet

03:07

since the model is three-dimensional

03:11

we call it as three-dimensional graphics

03:16

so computer graphics deals with

03:19

geometric modeling so this is an

03:21

artificial scene with uh

03:24

cones with donuts with the teapot and

03:28

with the lights and the windows

03:30

so in order to create an artificial

03:33

artificial image you need to model the

03:35

objects

03:36

on the scene

03:37

so that is called

03:39

as geometric modeling you need to model

03:42

for example the window with the length

03:44

and the orientation and the size and the

03:47

type and etc

03:51

then

03:53

using that model

03:55

with certain algorithms

03:58

you achieve the resulting image

04:02

through lighting equations through

04:04

rendering operation

04:06

through rendering operation you create

04:08

the image after the

04:10

after the model

04:13

sometimes this teapot is very famous and

04:16

that famous teapot is

04:18

drawn first in university of utah in the

04:22

utah

04:24

culture graphics group

04:26

for example

04:29

this is a cube

04:33

right

04:34

is this cube

04:40

of of this form

04:43

is this the front face or is this the

04:45

front face for example

04:52

this same cube image this is the

04:54

wireframe

04:59

the same wireframe image can be

05:04

can have two different forms

05:06

so depending on how you

05:09

depending on how you eliminate back

05:12

lines

05:13

the object is perceived better

05:15

so in this on this teapot for example

05:19

back lines

05:22

are not drawn

05:24

so one once you are drawing

05:27

the

05:29

once you are drawing the

05:43

once you are drawing the

05:47

[Music]

05:50

teapot you need to eliminate back faces

05:55

and the question is

06:01

what is at the back

06:07

what does it mean

06:09

what is back and what is front

06:11

in a

06:13

computer image because

06:15

i have two dimensional plane here this

06:18

is x and that is y

06:20

yet i see it as three dimensional image

06:23

so this is kind of a three-dimensional

06:25

teapot and since this this

06:27

three-dimensional teapot is

06:30

perceived as since you are intelligent

06:32

from the previous lecture remember since

06:35

you are intelligent beings you perceive

06:37

it as a teapot as a three-dimensional

06:39

object but this is

06:42

two-dimensional

06:45

it's not a picture of

06:49

two-dimensional thing it's a picture of

06:51

three-dimensional object so there are

06:53

there are back faces and those back

06:55

faces should not be drawn on screen so

06:58

you are the person in your algorithms

07:01

you are the person who is responsible

07:03

from not drawing

07:05

backlines

07:07

that means you need to determine which

07:09

is at the back which is at the front

07:12

by calculation

07:15

again in

07:18

in reality

07:19

there is a concept called shadows

07:22

when you have a light source

07:25

and an object and a screen

07:29

or some

07:30

surface

07:32

this object

07:34

casts a shadow

07:37

on the other side so each object has

07:39

shadow sometimes there are multiple

07:41

shadows

07:43

if you have multiple shutters

07:45

what is the cause

07:51

multiple light sources

07:53

so the location of the shadow depends on

07:55

the position of the light

07:57

etc so those must be calculated

08:02

those must be calculated and computer

08:04

graphics

08:06

does that

08:09

that is very that is not very hard there

08:11

are more harder things for example

08:14

uh if the if the light source is a light

08:16

source like that which is area light

08:18

source

08:20

what is the special kind of the shadow

08:22

the shadow boundaries are not

08:24

sharp we call them soft shadows

08:28

so creating soft shadows require a lot

08:30

of

08:31

thinking because

08:33

it is not only single light source

08:36

it is not parallel light source like

08:39

solar light source

08:41

where the

08:42

shadows are very

08:44

sharp

08:46

we consider that

08:48

we consider it as

08:51

tiny little small light sources

08:54

like

08:55

64 different light sources

08:58

close to each other

09:00

and we calculate

09:02

those small light sources

09:05

shadows

09:07

one after another and we add them up

09:10

if we add them up

09:11

then we end up with soft shadows

09:15

thanks

09:24

you guys can catch up later from the

09:26

video

09:30

next

09:32

what is this

09:34

this is the world

09:37

is this the world

09:39

or is this a

09:40

[Music]

09:42

sphere

09:44

it's actually a sphere

09:46

with a picture of world on top of it

09:50

when i'm drawing this i don't need to

09:53

model the world

09:54

all i have is a

09:57

sphere

09:58

and the map

10:00

so

10:02

this is this is a sphere so i can map

10:06

for example a turkish flag on it

10:11

so that means i have a sphere with

10:13

turkish flag wrapped around it

10:16

so we call it as texture mapping

10:20

it is actually

10:21

the picture of the world not the model

10:24

of the world but we can set it so that

10:27

it wraps around a sphere

10:30

and draw it on screen so we call it as

10:33

texture mapping it doesn't happen all “**Texture mapping** is a technique that gives a surface to a computer image or a computer 3D model. For example, a graphic artist may give a graphic object a stone texture, making the object look more like a realistic stone object. A user may also scan a surface of a real object, such as a person's face, and map it onto an object.”

10:35

the time with the

10:38

spheres when you have a street in for

10:41

example a computer game

10:44

this is a computer game that's the

10:45

street there are buildings on

10:48

on the side of the road and each

10:50

building has a face and those faces have

10:52

very good details

10:55

do i generate those details in the game

10:57

in the game no they are pictures those

11:00

pictures are stuck on the face of those

11:05

cubes or boxes

11:07

boxes represent buildings so i stick

11:11

images of the

11:13

real-life buildings on boxes so that a

11:16

box look like

11:19

a building

11:22

do you understand

11:23

so for example in computer games

11:25

graphics cards are responsible from

11:28

performing that operations those

11:29

operations but

11:33

the thing is somebody has to program it

11:37

it doesn't happen by itself

11:40

we say graphics card is responsible from

11:42

it yes but

11:44

somebody is programming

11:46

so that is the

11:48

job of computer graphics

11:53

sometimes

11:58

we have complex geometries like the

12:00

helicopter here

12:02

like a

12:03

car

12:04

when you are driving the car when you

12:06

are drawing the car

12:09

it has a door and window and front glass

12:13

windshield tires

12:15

so there are thousands of pieces

12:18

those pieces must be put together in a

12:20

data structure maybe in 3d three data

12:22

structures so different data structures

12:25

must be put together

12:27

to construct a complex

12:30

image

12:31

that kind of

12:32

complex geometry and modeling that

12:35

geometry for example if it's going to be

12:37

an interactive interactive editing

12:38

graphics you can open this door

12:41

when you open this door the rest of the

12:43

car should stay intact

12:46

so it can be opened and closed in the

12:48

model therefore you need to define the

12:51

connections connection points and joints

12:53

in between

12:55

like like a simple robotics problem

12:58

so that is

12:59

uh

13:00

the topic of computer graphics

13:03

dealing with complex geometries and

13:05

complex objects

13:09

second

13:12

remember smells

13:30

this is ni this is ns this is again ni

13:34

so we have snell's law

13:40

so there is angle of is theta i

13:44

and theta s

13:48

that so you have been solving questions

13:50

all along

13:52

for the past years

13:54

so using that equation

13:57

i can

13:58

calculate how transparent objects

14:01

looks like how

14:03

water looks like how the fish

14:06

how the fish in an artificial pond

14:10

should be drawn

14:12

how the atmospheric effects in

14:14

artificial

14:16

animations

14:18

can be emulated

14:21

so that is called this calculation of

14:24

Transparency “ Transparent surfaces permit all light to pass “

14:25

therefore i can simulate glass for

14:28

example i can have glass lenses i can

14:30

have glass balls

14:32

i can have glass balls where i can see

14:34

behind as upside down

14:36

because i am calculating

14:40

transparency

14:44

effects

14:46

by

14:48

by following the path of the light

14:51

and

14:52

drawing what is necessary on screen

14:55

after the calculation

15:00

this is an interesting again university

15:02

of utah teapot the model is typha the

15:04

famous teapot model

15:06

uh

15:07

here we see that there is a person

15:10

on this side maybe it is our image

15:14

like when you are holding a teapot the

15:16

shiny teapot right

15:18

uh you are seeing yourself so if i am

15:20

going to

15:21

simulate that

15:23

i need to have this kind of picture

15:25

but

15:26

do i have a teapot

15:30

answer me

15:36

no

15:38

thanks for

15:39

thanks for answering though

15:41

because i don't have the teapot

15:43

i the teapot is on the computer

15:47

one question was when i have a circle

15:50

on the computer how am i going to store

15:52

the circle in the computer memory

15:56

the answer was store the origin

15:59

and radius

16:01

when you store the origin and radius

16:04

that's a circle so in the computer

16:06

memory when i have a teapot in computer

16:09

memory

16:10

do i have it in real life

16:13

no

16:14

but i want my image as if i have it

16:17

how am i going to do it

16:21

because teapot doesn't exist

16:24

this could be a dragon

16:28

so we all know that dragons do not exist

16:31

or

16:33

or an animal that is an extinct for

16:35

example a dinosaur

16:36

a dinosaur

16:38

and on the eye of the dinosaur i see

16:40

myself

16:42

so do i need a dinosaur to take that

16:44

shot no because there is no dinosaur

16:46

available

16:48

so i have a dinosaur model

16:52

i have my

16:54

basically image

16:56

right i have my photograph

16:58

so using my photograph and

17:01

dinosaur model i can simulate

17:05

the effect that my image is shining on

17:08

dinosaurs eye

17:10

or on teapot

17:12

so that is called as environment mapping “Bilgisayar grafiklerinde, çevre haritalama veya yansıma haritalama,(environment mapping) önceden hesaplanmış bir doku aracılığıyla bir yansıtıcı yüzeyin görünümünü yaklaşık olarak belirlemek için etkili bir görüntü tabanlı aydınlatma tekniğidir. Doku, işlenmiş nesneyi çevreleyen uzak ortamın görüntüsünü depolamak için kullanılır.”

17:15

that is environment mapping maps

17:18

similar to texture mapping

17:21

maps an image

17:22

on an object as if the image is

17:27

surrounding or across

17:30

the uh across the model so teapot

17:34

doesn't exist but i create an image

17:37

as if i am on the other side

17:41

this is extremely important when you are

17:43

generating a when you are launching uh

17:47

this is the new

17:51

card that we are making

17:53

right

17:55

sorry for the drawing

17:57

it is much better

17:59

actually

18:00

so assume that

18:02

i am taking an

18:04

animation movie

18:06

showing the

18:08

pog car

18:09

driving

18:11

in sultan

18:12

amit right

18:15

so

18:16

that's an animation

18:19

but when the car is driving through

18:20

truth

18:22

since the car is so shiny

18:25

on the windshield and on the body

18:28

in the animation in the film animation

18:31

realistic animation i should see the

18:33

surrounding

18:36

aya sofia and the trees

18:38

on the car

18:39

because it is so shiny

18:42

but the car doesn't exist

18:48

i need the movie my boss

18:50

the

18:51

president finds it so

18:54

how am i going to

18:55

make the movie

18:57

the answer is

18:59

i

19:01

take

19:02

a video

19:04

by following the path

19:06

in sultanamet

19:09

route

19:10

with a car with my car

19:12

take the surrounding image

19:16

take the outside take the video of

19:19

aya sofia and the trees etc in the same

19:22

path using that video with the same

19:26

technique

19:27

i can compute the reflections on the car

19:30

this doesn't exist yet

19:34

so if i make the correct computations i

19:36

can

19:38

make the appearance of the artificial

19:41

car

19:42

so that when it is passing through aya

19:44

sofia the image of the aya sofia minaret

19:47

will be visible on the car's body

19:50

actually the car doesn't exist

19:53

because

19:54

i passed through that

19:56

route with my car took the video and i

20:00

stick to that video

20:01

on the body of the model

20:04

okay this is what environment mapping is

20:06

and environment mapping can be done on

20:08

videos as well

20:12

so computer graphics is very famous in

20:16

computer games and computer game

20:18

technologies and the industry

20:22

is quite significant you can make a lot

20:25

of money money by writing and

20:28

working in computer game companies

20:33

the the level of the level of uh

20:37

computer graphics necessary for

20:40

creating good computer games

20:42

is quite significant

20:45

uh

20:46

the techniques are

20:48

relatively different

20:50

in computer games

20:53

because

20:55

speed is important

20:58

accuracy is

20:59

less important

21:01

so fast generation

21:03

of

21:04

usually fake

21:08

graphics

21:10

is acceptable because if user likes it

21:14

then it is correct

21:16

so for example when you need a smog when

21:19

you need

21:20

when you need fog for example

21:22

there is fog here

21:24

when you want to make it this

21:28

fog with an algorithm

21:31

how are you going to do it

21:35

you don't make physical simulations of

21:38

the fog

21:39

because when you want to make a physical

21:41

simulation of the fog the particles are

21:43

moving etc

21:44

which is very difficult so what you do

21:47

is

21:48

make an image

21:50

image

21:51

superposition

21:53

stick that figure

21:55

on top of the previous image now users

21:58

see it as a fog so no problem

22:01

because it is fast

22:03

so that kind of tricks that kind of

22:05

tricks and speed improvements

22:08

are

22:09

used in computer games so that you can

22:12

enjoy

22:14

fast moving graphics rather than 100

22:17

correct

22:18

animation

22:23

another

22:24

money money-making topic in computer

22:27

graphics is a medical application

22:29

so

22:30

whether you have tomographical images

22:33

whether you have ultrasound images

22:36

there is medical data

22:38

coming from the scanning devices from

22:41

tomographic

22:42

or

22:44

magnetic resonance imaging units and

22:48

ultrasound

22:49

etc

22:51

at the end

22:53

the data must be visualized

22:56

shown to doctor

22:58

and doctor will say aha let's cut this

23:01

part out

23:03

and probably they will take more money

23:05

than you

23:07

uh

23:08

that is

23:10

that may not be true in coming years

23:14

the important thing is

23:16

they look at the image and decide

23:18

whether you have cancer or not

23:22

by visualization

23:24

with good visualization technique

23:27

you can help doctors to understand the

23:30

cases better

23:32

solve problems better

23:34

or furthermore

23:35

those data can be analyzed by artificial

23:38

intelligence that you learned in the

23:39

previous hour

23:41

to detect

23:42

where is the sick part but is there a

23:45

problem or not

23:46

is there a cancer or not so the success

23:49

rate of algorithms

23:51

are

23:51

in these years are

23:53

passing the doctor's performance so

23:56

performance of performance of algorithms

23:58

for medical applications signal

24:00

processing applications are increasingly

24:03

surpassing

24:05

doctors performances especially poor

24:07

doctors performances

24:15

during

24:16

during operations

24:18

during amelia operations uh doctors

24:22

surgeons can be supported with computer

24:24

graphics applications so that they can

24:26

see inside of the patient in real time

24:30

you can combine you can combine the

24:32

information

24:33

during the operation

24:36

that that is received from the external

24:38

sensors like ultrasound or

24:40

mr or whatever or the previously or

24:43

previously generated data so that doctor

24:46

will see inside

24:48

the human body or make certain decisions

24:51

based on

24:54

what was wrong with the patient so

24:55

medical applications of the computer

24:57

graphics is seriously important

25:02

and in production

25:05

in design of design of

25:07

mechanical physical electronic systems

25:10

computer graphics is quite significant

25:11

because

25:13

as you are designing it you need to see

25:15

it

25:16

therefore modeling

25:18

phases visualizing phases

25:20

uh compensated design applications

25:22

require extensive amount of computer

25:25

graphics of computer graphics

25:28

programming

25:30

this is a chip

25:32

this is a transistor for example

25:35

a transistor

25:36

so

25:37

designing of

25:44

graphics

25:50

furthermore

25:51

biotechnology dna

25:54

sequencing astronomy radio radio

25:57

astronomy

26:00

chemistry biology

26:03

sometimes mathematics

26:06

requires

26:09

certain tasks called as scientific

26:11

visualization

26:12

scientific visualization

26:16

helps scientists to understand

26:19

things better and solve

26:22

life's existing problems solve

26:25

nature

26:26

underlying issues

26:28

and develop theories

26:31

so this for example

26:32

these

26:33

distant galaxies are not visible by

26:36

telescopes

26:37

not visible by

26:39

naked eye not visible by anything they

26:41

can already visible after processing

26:44

and colorizing

26:47

radio telescope data

26:50

organizing data and putting them on the

26:53

screen then they will then you will say

26:56

ah there is a galaxy actually that image

26:59

is computer generated

27:06

lastly

27:09

the animation industry is

27:12

improving every day

27:18

with the advent of

27:22

augmented reality and

27:24

virtual reality

27:26

industry is shifting through

27:29

three-dimensional

27:30

synthetic environments

27:33

uh as you remember recently facebook had

27:36

a different company what was the name

27:42

in the meta uh they are going to

27:46

work on metal worlds

27:49

in future the environments like social

27:53

environments like social media

27:55

will be virtual worlds

27:58

where you can interact with your

28:01

senses

28:02

in three-dimensional plus

28:07

sound

28:08

vision sound

28:09

and

28:11

probably

28:12

extra additional senses that we cannot

28:14

think of yet like smell and touch

28:18

patch is also

28:20

tested years before

28:22

there are

28:23

there are cases when you there are

28:25

examples where you

28:27

stimulate certain fields of touch with

28:30

the globes etc

28:32

uh they're also working on putting some

28:34

transceivers at the back of your back of

28:36

your head so that you can feel certain

28:40

also punches

28:43

after processing with electrical signals

28:46

at your brain

28:49

so

28:50

themes and animation plus virtual worlds

28:54

for entertainment and human interaction

28:57

is quite significant

28:58

topic in

29:00

graphics

29:06

the famous

29:07

question that comes from students

29:12

there are there is a topic called work

29:14

area called

29:16

image processing

29:18

and computer vision

29:22

so we ask

29:23

what are you doing

29:25

i'm on to computer vision okay

29:28

what are you doing i am doing image

29:30

processing these are

29:32

relatively

29:34

older

29:35

topics

29:37

where

29:39

they mostly deal with

29:41

image enhancement

29:43

feature extraction and pattern

29:45

recognition

29:47

when you talk about 3d model extraction

29:51

more like computer vision

29:55

so that requires

29:57

you to have

30:00

photographs or video

30:03

at the beginning

30:04

so photograph of a real object is taken

30:09

and then processed

30:10

that is what we call image processing “ **image processing**, set of computational techniques for analyzing, [enhancing](https://www.merriam-webster.com/dictionary/enhancing), compressing, and reconstructing images. Its main components are importing, in which an image is captured through scanning or digital photography; “

30:13

and for that purpose

30:17

we use a lot of mathematics and fourier

30:19

transforms and

30:22

there are electric electrical and

30:23

electronics engineer departments people

30:26

working on that topic as well or

30:28

mathematicians

30:29

to improve

30:33

image for example to sharpen the image

30:36

to

30:37

colorize the image or just squeeze the

30:39

image

30:40

etc

30:41

but to detect whether there is a house

30:46

and tower here and the house has how

30:49

many floors this house has for example

30:51

that answering that kind of intelligent

30:53

question

30:54

is the top is the

30:57

topic of

30:58

computer vision

31:00

and computer vision is therefore quite

31:02

important for industrial manufacturing

31:05

where you

31:06

value monitor

31:09

the objects

31:10

in production and

31:12

process them

31:14

locate them and process them

31:17

the help of the camera

31:20

along with the robotics so computer “ Computer vision is a field of artificial intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs — and take actions or make recommendations based on that information. If AI enables computers to think, computer vision enables them to see, observe and understand.”

31:22

vision and robotics go together in

31:24

industrial manufacturing also for

31:26

example

31:27

a couple of days ago i saw a machine in

31:30

the video i saw a machine that goes in

31:32

the

31:37

livestock

31:39

milk milk factory with the cows

31:43

they automatically take milk from the

31:44

cows a robotic robotic device goes by

31:48

itself detects cows back

31:50

approaches

31:52

makes the cow and

31:56

pulls itself back so moves to the next

31:59

car nobody is interfering so it is all

32:02

by 3d model extraction computer vision

32:05

etc so i i showed the

32:08

video to one of my friends who is doing

32:11

that kind of business

32:13

uh he has a farm

32:14

and he said the machine also gives

32:16

electrical jobs electrical pulse to carb

32:19

so that the pulse after milking the cow

32:22

goes away

32:23

with the shock electric

32:25

that's light electric

32:27

otherwise he said house doesn't move

32:29

away from the robot

32:32

so it is all connected

32:38

what is computer graphics then

32:40

computer graphics

32:42

does not have photographs does not have

32:44

real life objects

32:46

compute graphics create

32:49

what is

32:50

unavailable

32:52

okay

32:53

you have

32:55

image

32:57

and when you go to three-dimensional

33:00

three-dimensional model

33:02

this is computer vision but when you

33:04

have three-dimensional

33:06

model

33:07

and you want to con

33:09

you want to create an image this is

33:11

computer graphics so they are in

33:13

different directions they are usually

33:15

related

33:16

but works in differently relation

33:18

different directions

33:21

you have model you want to go to image (computer graphics)

33:23

you have image or you want to go to (computer vision and image processing)

33:24

model

33:26

33:37

these are the examples from uh

33:40

computer vision image processing for

33:42

example detecting edges

33:44

edges of two objects

33:46

this is the original this is a better

33:49

image

33:50

we call it as sharpening

33:56

derivatives

33:58

derivatives in two dimensional space

34:00

when you use derivatives in two

34:02

dimensions and adjusted

34:12

that is called as sharpening or if you

34:15

take

34:16

values

34:17

uh

34:20

that derivative is bigger than talking

34:23

to the point value

34:24

then you get an

34:29

processor where the changes are

34:31

significant

34:33

when the changes are significant they

34:35

become boundaries

34:38

so that is for example used to

34:41

detect

34:42

images

34:44

detect objects in the image

34:47

with the boundaries

34:50

graphics is cool

34:52

i'd like to see what i am doing graphics

34:54

is interesting it includes physics

34:58

mathematics algorithms architecture

35:00

gaming human factors it's a it is

35:02

combination of a lot of different

35:05

issues and recently

35:07

artificial intelligence also going into

35:09

computer graphics

35:16

it is also uh it also includes a lot of

35:19

fun

35:21

you can enjoy it while you are doing it

35:29

this is from the

35:30

pixels

35:31

pixels first film

35:35

[Music]

35:40

and one of my one of my friend actually

35:42

worked in production of this game in

35:45

1990

35:52

96 i think

36:05

the guy got his phd from our school in

36:08

united states

36:10

and the same lab uh in 1990

36:16

four

36:17

and

36:18

joined to pixar

36:20

he was responsible for making this

36:24

[Music]

36:25

figure

36:32

um

36:34

this is the last

36:35

thing i am going to show you

36:37

and

36:38

i will continue next week

36:41

when you are

36:42

when you are seeing certain things

36:45

see

36:45

seeing it seeing this believing

36:48

if you see something

36:50

you perceive it so

36:52

it actually happens by

36:54

a light source light source illuminates

36:58

objects

37:00

and

37:01

certain light comes back to your eyes

37:04

so if you understand this process and if

37:06

you can simulate what is happening if

37:08

you can calculate what is happening

37:10

that means you can fake

37:14

fake to computerize so that when you see

37:16

it okay

37:17

it's a picture

37:20

or if it isn't stereographics with the

37:23

helmet

37:24

you may believe it

37:28

you may believe that it is there

37:34

okay

37:35

i think it's good for today

37:37

if you have any questions

37:39

i can take it

37:46

[Music]