Professor Anil Kokaram

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5C1 Motion Picture Engineering

Digital Video Engineering

Engineering for Moving Pictures

Career

- 1986 – 1989 Electrical and Information Sciences @ Cambridge Uni
- 1989 – 1993 Ph.D Cambridge University DSP Group www-sigproc.eng.cam.ac.uk
- 1993 – 1997 Research Fellow Cambridge Uni and Churchill College Cambridge
- 1998 – 2011 Professor, www.sigmedia.tv, EE TCD
- …

Research in

Digital Signal Processing
Digital Video Processing
Motion Picture Restoration

Anything to do with pictures and sound or interesting data

www.sigmedia.tv

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- 2007 Academy Award for Motion Estimation FX


79TH
ANNUAL
ACADEMY
AWARDS®
EXIT
EXIT


Trinidad and Tobago
YouTube
Beaufort Sea
Baffin Bay
Arctic Circle
Alaska (USA)
Canada
Hudson Bay
Labrador Sea
Iceland
Gulf of Alaska
United States of America
NORTH ATLANTIC OCEAN
Bermuda (U.K.)
Haiti
Dominican Rep.
Bahamas
Mexico
Gulf of Mexico
Cuba
Jamaica
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Hawaii Islands (U.S.)
Tropic of Cancer
Canary Islands (Spain)
Cape Verde
Puerto Rico(U.S.)
St. Kitts And Nevis
Antigua and Barbuda
Dominica
St. Lucia
Barbados
Trinidadn& Tobago
Guyana
Brazil
Paraguay
Uruguay
Ascension (U.K.)
St Helena (U.K.)
Trindade (Brazil)
SOUTH ATLANTIC OCEAN
Ivory Coast
Gambia
Sierra Leone
Senegal
Mauritania
Western Sahara
Morocco
Algeria
Tunisia
Libya
Egypt
Mali
Niger
Chad
Sudan
Nigeria
Burkina Faso
Central African Rep.
South Sudan
Eritrea
Ethiopia
Djibouti
Yemen
Somalia
Uganda
Kenya
Gabon
Congo
Dem. Rep. Congo
São Tomé and Principe
Tanzania
Angola
Zambia
Zimbabwe
Namibia
Botswana
Madagascar
Mozambique
Swaziland
Lesotho
South Africa
Comoros
Seychelles
Mayotte(France)
Mauritius
Reunion(France)
INDIAN OCEAN
Ukraine
Romania
Bulgaria
Greece
Turkey
Georgia
Azerbaijan
Armenia
Uzbekistan
Turkmenistan
Kyrgyzstan
Tajikistan
Kazakhstan
Russia
Mongolia
China
North Korea
South Korea
Iran
Iraq
Syria
Jordan
Kuwait
Bahrain
Qatar
Saudi Arabia
U.A.E.
Oman
Yemen
Afghanistan
Myanmar (Burma)
Laos
Thailand
Vietnam
Taiwan
Philippines
Brunei
Malaysia
Singapore
Indonesia
Java
Sumatra
East Timor
Sri Lanka
Andaman Is.(India)
Cocos Is. (Aus.)
Christmas Is. (Aus.)
Australia
Great Australian Bight
Kara Sea
Sea of Japan (East Sea)
East China Sea
Philippine Sea
Arabian Sea
Red Sea
Mediterranean Sea
San Marino
Monaco
Andorra
Spain
Portugal
Vatican City
Italy
Malta
Israel
1. Netherlands
10. Austria
20. Ghana
29. Liechtenstein

GREEN PARROT PICTURES

Restoration Enhancement Conditioning

Leaders in Video Motion

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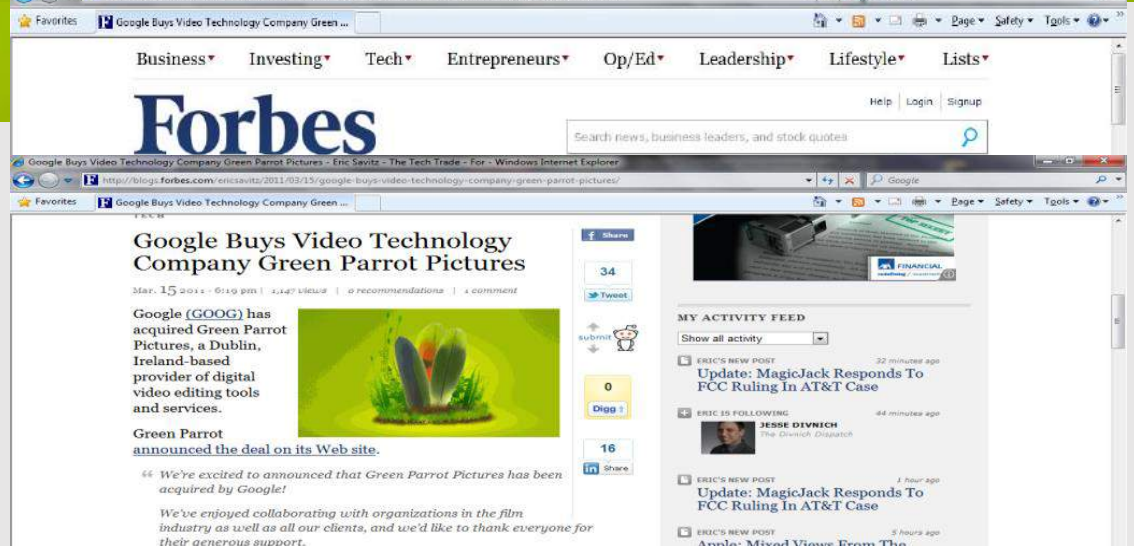

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YouTube

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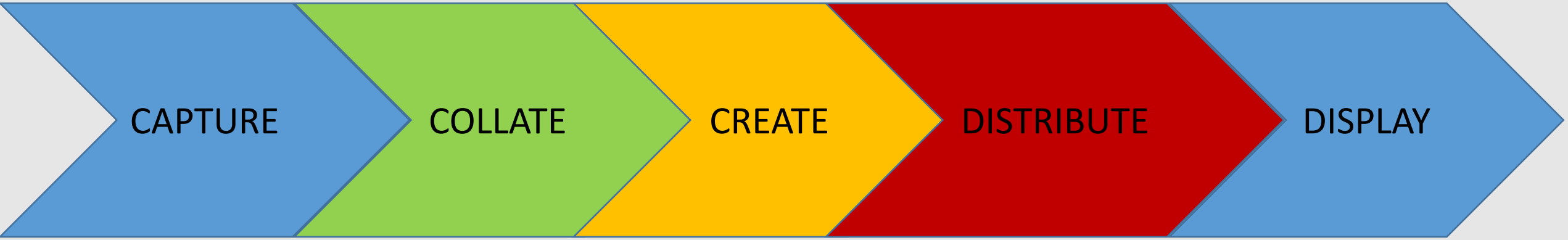
- 2016 – Head EE @ TCD

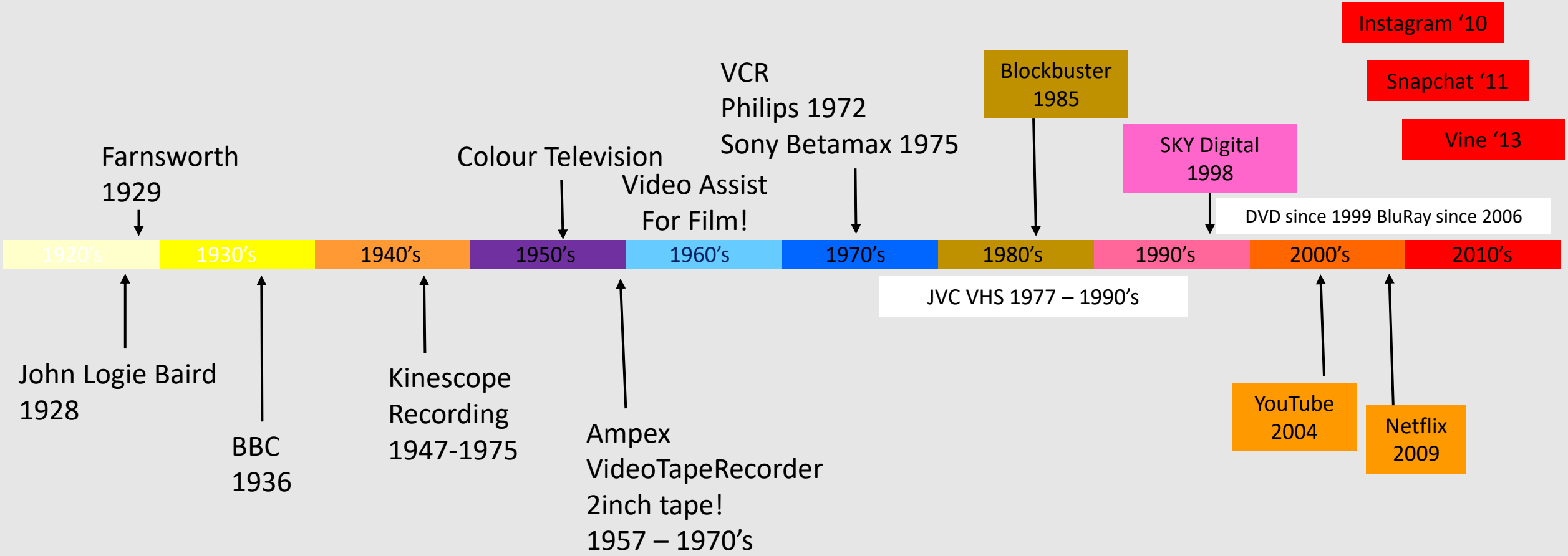
70% internet is video

1 Billion hours on YouTube

40% of the world owns a smartphone

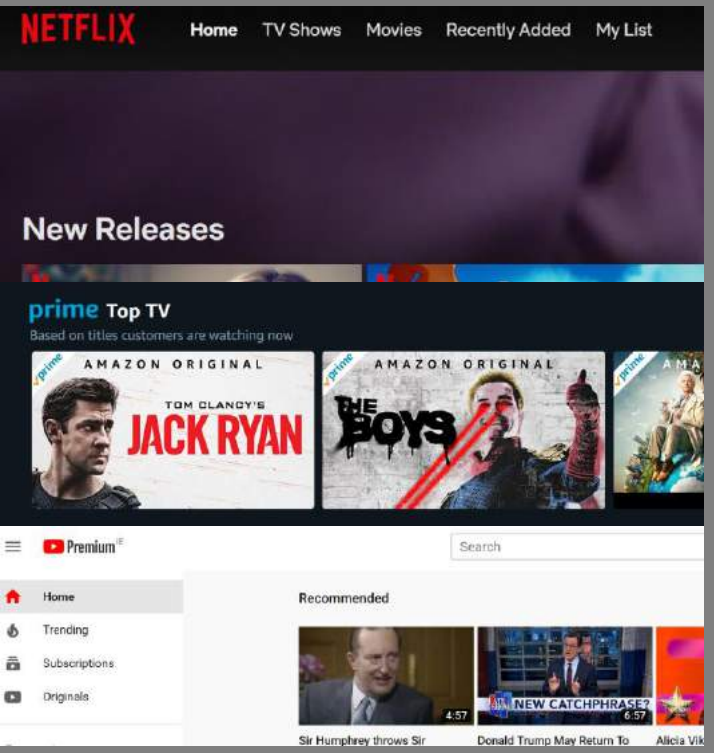

CAPTURE
COLLATE
CREATE
DISTRIBUTE
DISPLAY

The history of Video/Television

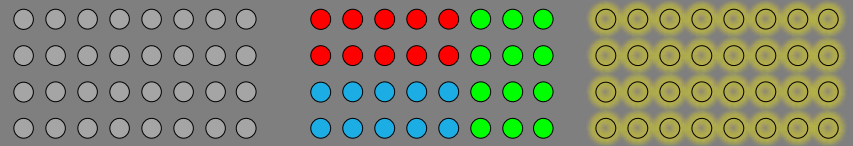


2016 was 80th anniversary Television
1999 was the 100th anniversary of the Cinema

Since 2015



Streaming Media reaches consumers through new picture tech BEFORE traditional broadcasters



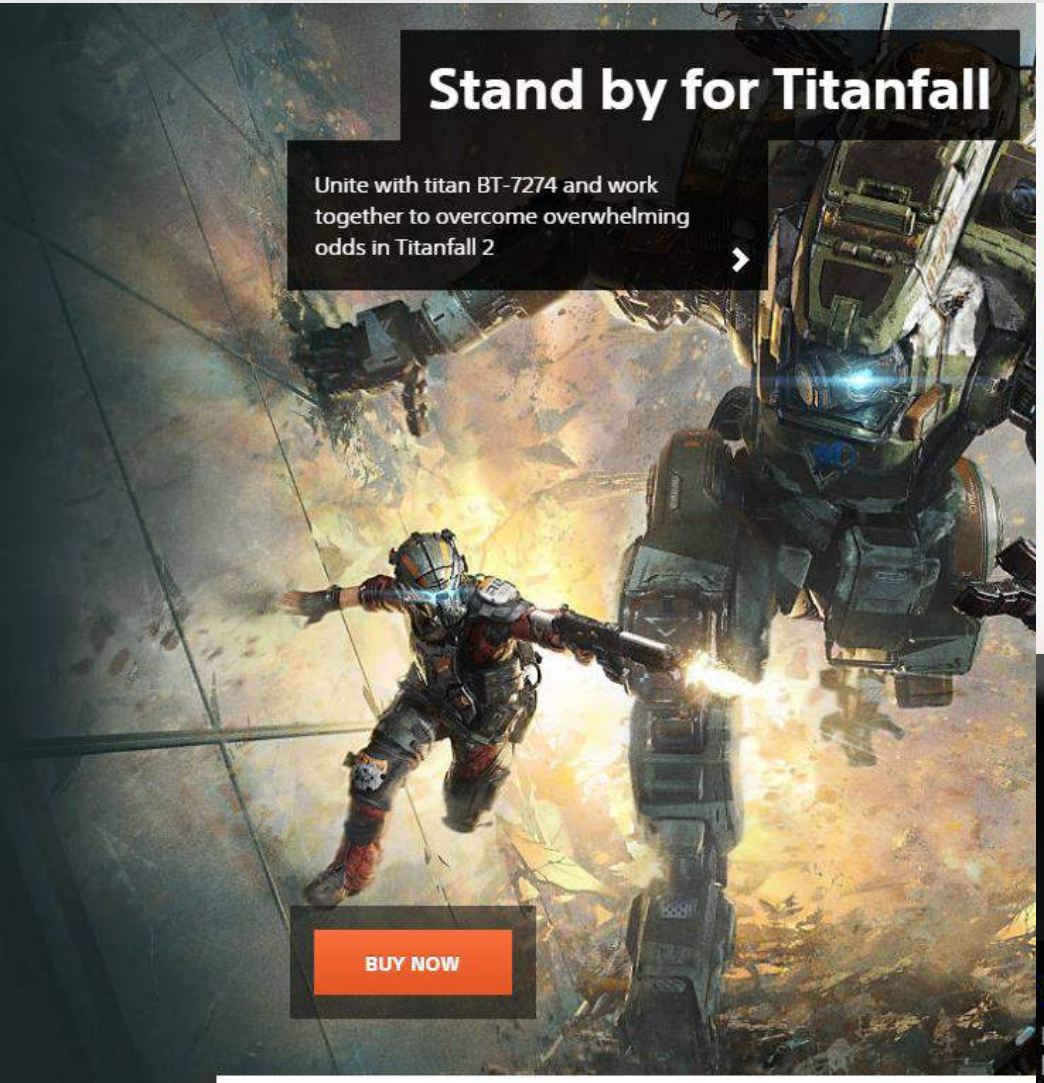
More Pixels (4K, 8K)
Better Pixels (10bits, HDR)
Faster Pixels (60, 120 fps)
Deeper Pixels (RGBX)
Open Royalty Free Video Standards

Simple computational tasks are complicated at scale.

We have come full circle.

Hardware, Compression, “DSP” Back on the agenda

Entertainment Drives Technology



Pandemic Drives Entertainment

How Zoom defied its critics and became the go-to video conferencing app for surviving the pandemic

By Jerry Bowles January 18, 2021 7 min reading

SUMMARY: What's next for the insanely popular, death-defying video conferencing phenomenon?

in a moment, but first, let's skip to the good parts.

4. Now the race is on for more content

The shutdown in film and television productions, forced by lockdowns this spring, has placed a major focus on how Netflix and its competitors will get hold of new offerings to retain their members.

Thanks to thousands of Motion Picture Engineers working on Video Compression Standards, New Technologies for content production and real time video communications …. The world didn't stop in March 2019. Quite a lot of people were able to continue working and Universities didn't quite close.

Netflix crosses 200m subscriber mark in pandemic-boosted year

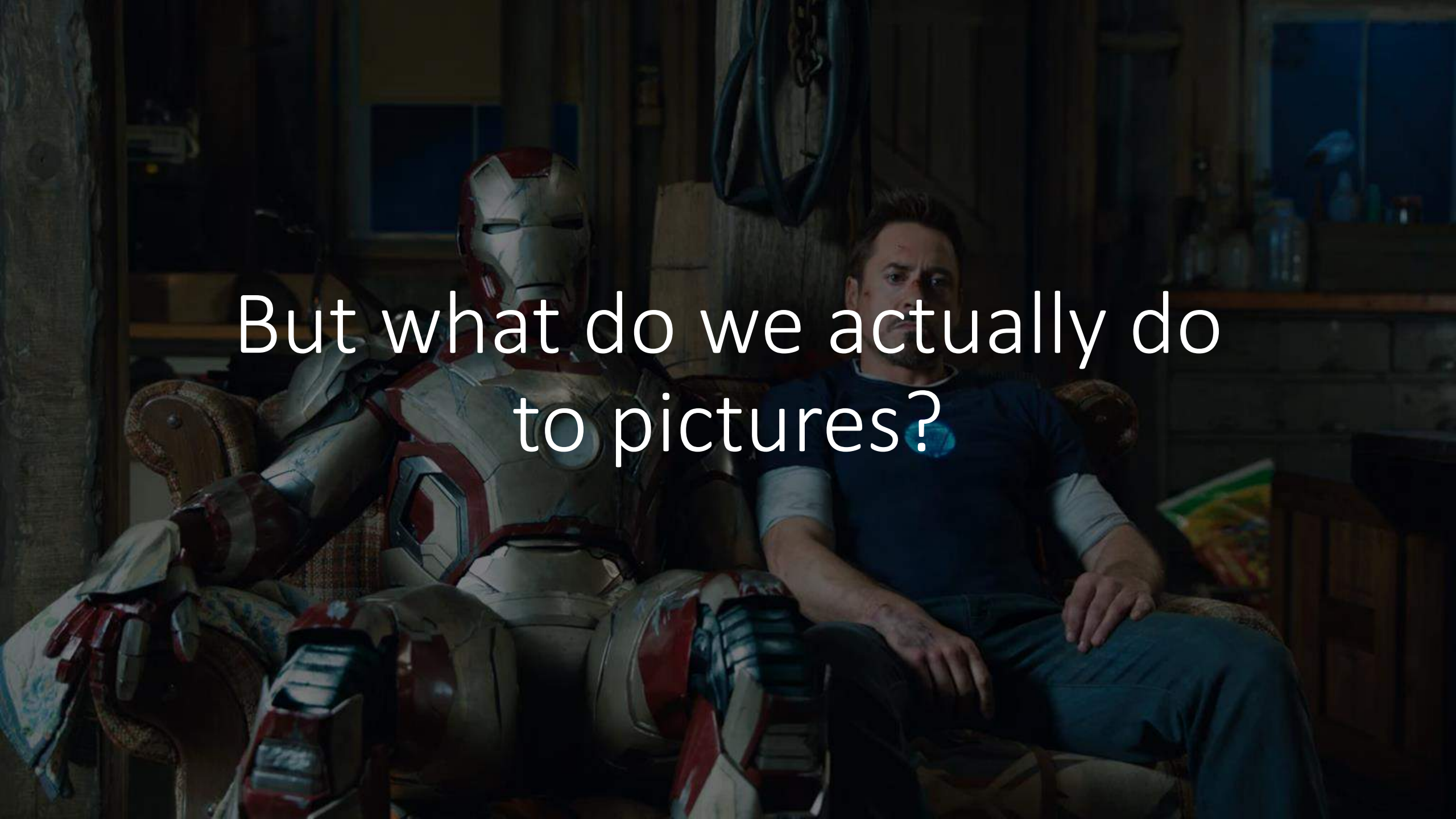
Covid-19 accelerated 'big shift from linear to streaming', says chief financial officer

Wed, Jan 20, 2021, 12:58 | Updated: Wed, Jan 20, 2021, 15:19

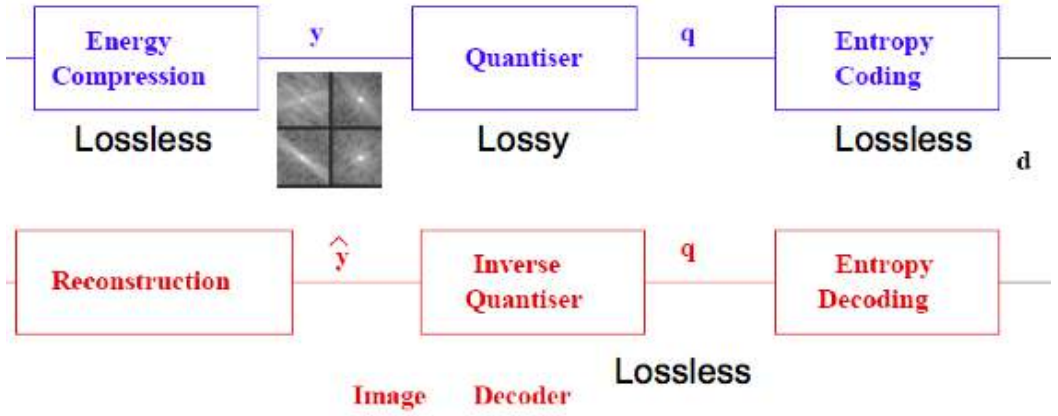
Netflix's Bridgerton, featuring Claudia Jessie (left) and Irish actor Nicola Coughlan, is on track to reach 63 million households, the streamer said. Photograph: Liam Daniel/Netflix

@Netflix in Los Gatos

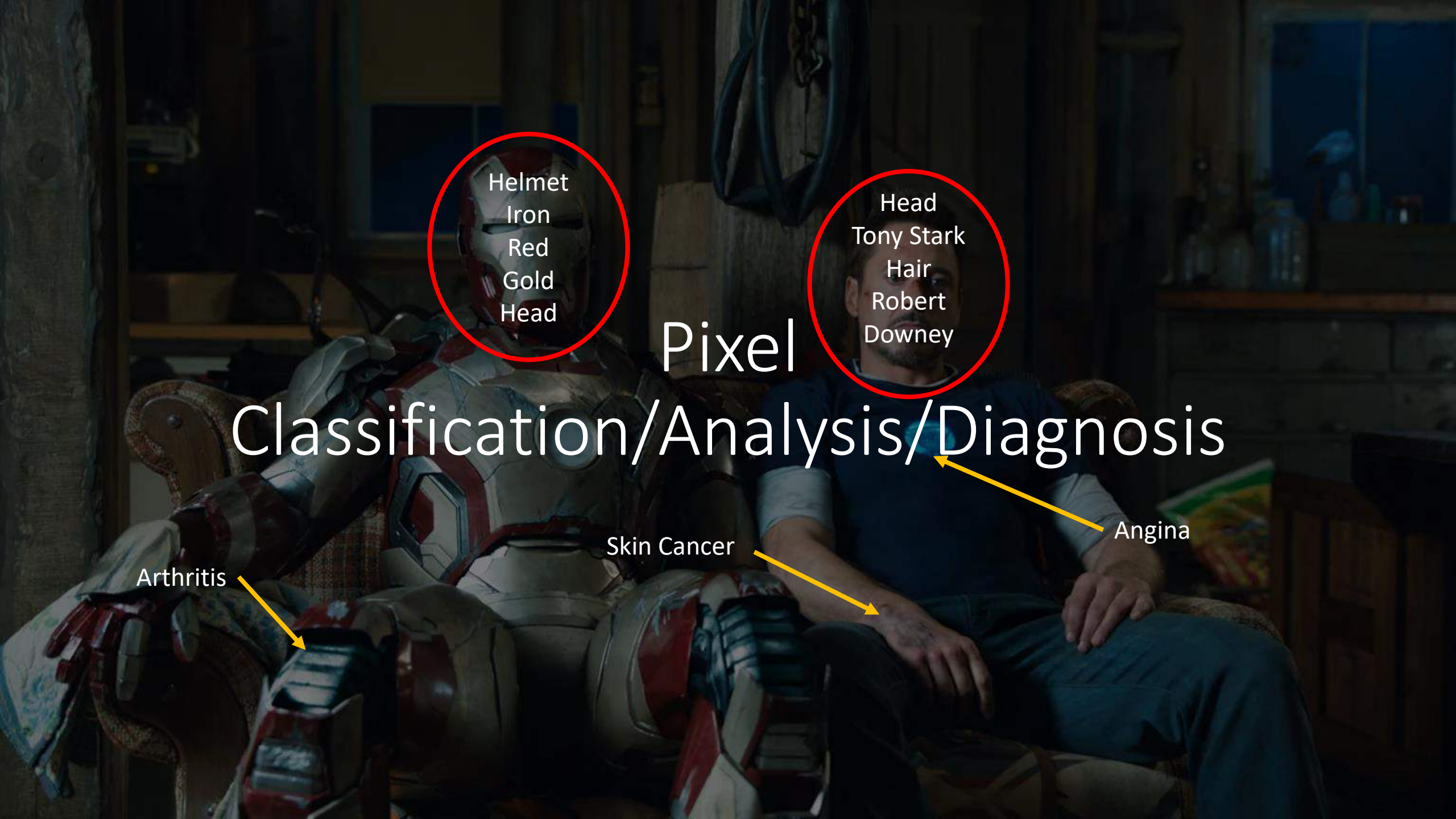
VIDEO QUALITY EXPERTS GROUP MEETING @SKY CENTRAL, LONDON


But what do we actually do to pictures?

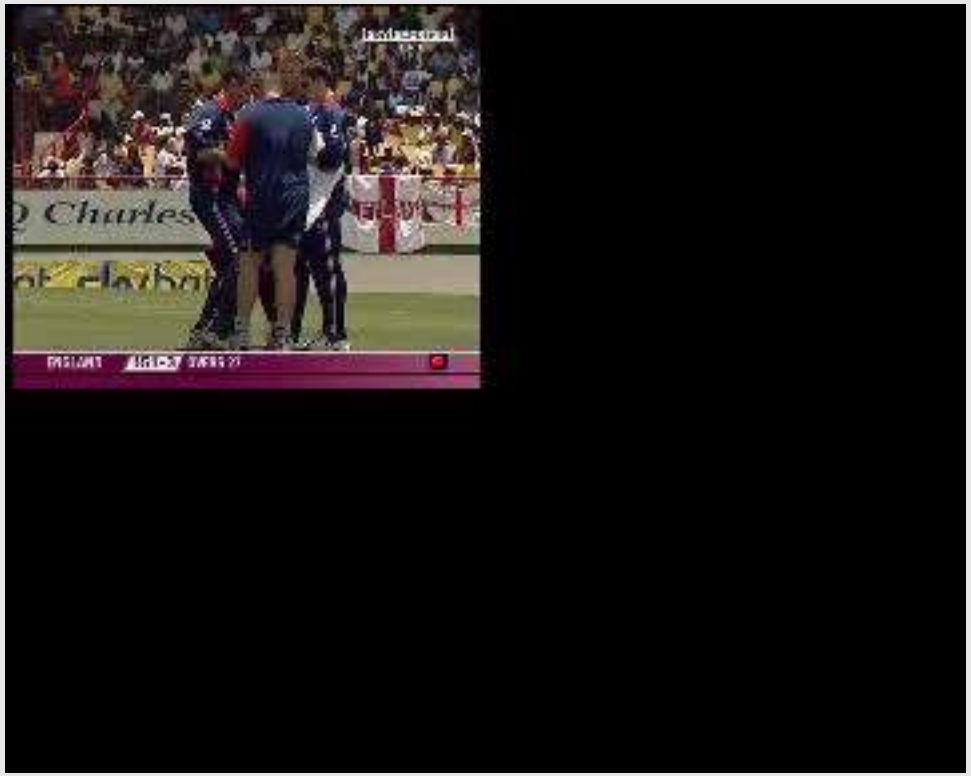
Pixel Pushing/Prodding



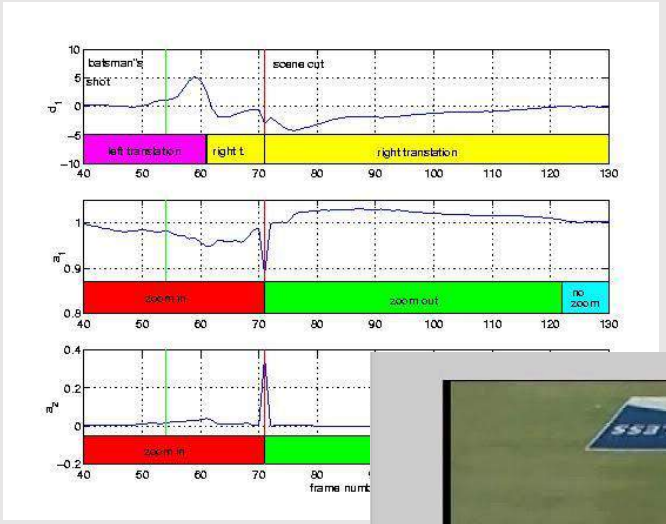
Pixel Communications


Helmet
Iron
Red
Gold
Head
Head
Tony Stark
Hair
Robert
Downey
Pixel
Classification/Analysis/Diagnosis
Angina
Skin Cancer
Arthritis

Using audio and video for content analysis



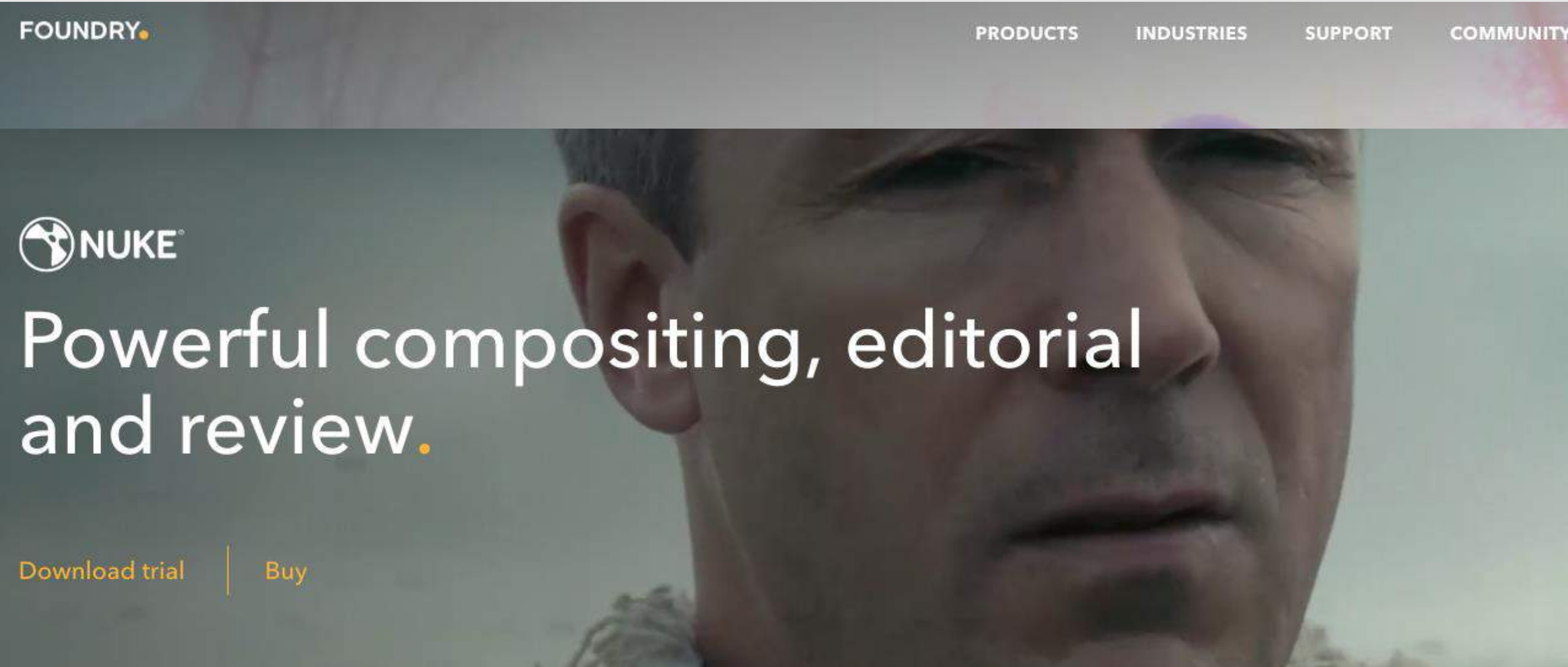
Audio



5C1 : Motion Picture Engineering

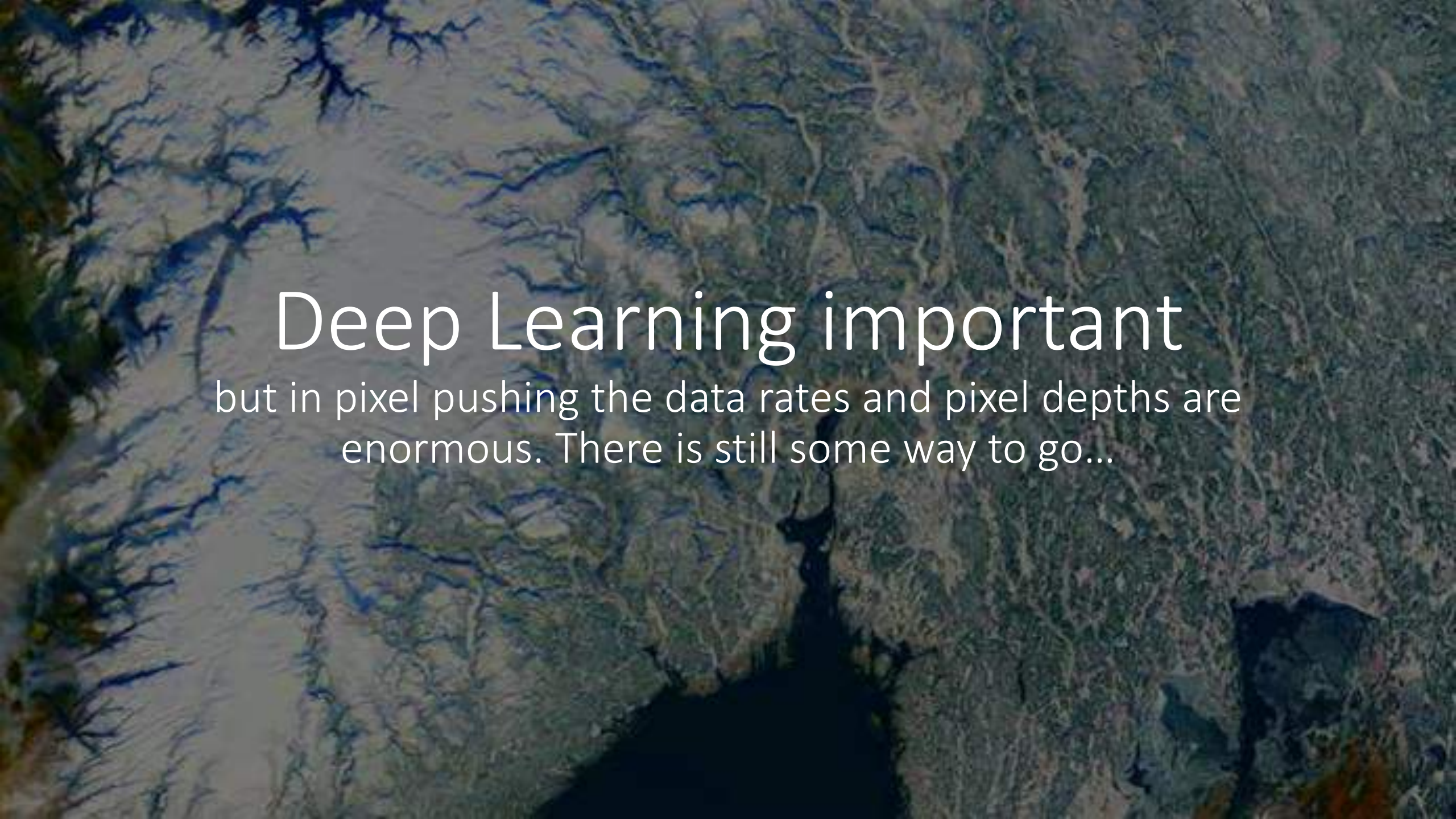
- Pixel Pushing (The invisible tools for making better pictures)
- Pixel Communications (Video Streaming)
- Pixel Quality Measurement

This course considers motion pictures in 2D+Time
We don’t process the images in the 3D world or do 3D modeling
We also spend a lot of time thinking about actual production and broadcast workflows.
This is not a normal image/video/computer vision course


FOUNDRY.
PRODUCTS
INDUSTRIES
SUPPORT
COMMUNITY
NUKE
Powerful compositing, editorial and review.
Download trial
Buy

Motion Picture Engineering Changes….

- Deep Learning is now changing everything !
- You will have to face the realities of more automation and intelligence in everything.
- The next Industrial revolution
- Affects medicine, bioengineering, mechanical engineering, civil engineering, creative technology
- See this
- In 2019 I was working on a DNN portion of this course .. That got hit in the face on March 2019 and is still on the mat.


Deep Learning important
but in pixel pushing the data rates and pixel depths are enormous. There is still some way to go…

Course Content

- Week 1 Introduction + Colour Segmentation
- Week 2 Perception and Bayesian Inference for Colour Segmentation
- Week 3 Video Processing and Motion Estimation
- Week 4 Deep learning and motion estimation
- Week 5 Applications in Video Processing
- Week 6 Another introduction to compression
- Week 8-12 Modern Video Compression and the Engineering behind YouTube and Netflix

Practical Work

- Week 1+2 : NUKE for Compositing
- Week 3 : Scripts in NUKE for video processing
- Week 4 – 6 : Writing your own script/graph for colour keying in video and writing a 4 page report
- Week 8 – 12 : Video Transcoding and Quality Measurement

Course Texts and Online Resources

Texts

- **Video Processing, Murat Tekalp**
- Markov Random Fields for Vision and Image Processing. Edited by A. Blake, P. Kohli and C. Rother, MIT Press, 2011. ISBN: 978-0-262-01577-6
- The Essential Guide to Video Processing. A. Bovik, Academic Press, 2009. ISBN: 978-0-12-374456-2

Online Resources

- IEEE Explore
- Various papers I will point out
- YouTube links as we go
- Shapiro's course on "Mars to Hollywood" and Katsagellos "Video and Image Processing" are references

The technical material discussed in this course is at the bleeding edge of what is possible. Get comfortable with not being able to find a complete set of notes like you'd find in a book which you can then just learn off. The book is still being written.

		9	10	11	12	13	14	15	16	17
Monday	Lecture	EEP55M08 - M17	EEMT17 - MMTLAB	EEMT17 - MMTLAB	EE5C01 M21	EEP55M08 - PBLT	EE5M02 - SPSR CS7NS6 - 1.07 LLOYD	EE5M02 - SPSR CS7NS6 - 1.07 LLOYD	EE5C01 - DO CS7NS5 - LB01	CS7NS5 - LB01 EE5M01 - M20
	Tutorial									
Tuesday	Lecture	EEP55M08 - SYNGE	EEP55C25 - CEDR CS7NS6 - 1.07 LLOYD	EEP55M08 - AP2.28 CS7GV5 - 4.09 LEINSTER		CS7GV3 - 1.20 LLOYD	CS7GV3 - 1.20 LLOYD EE5M02 - AP2.02	CS7DS2 - LB04 EE5C01 - AP2.28	EE5C01 - AP2.28	EE5M01 - AP2.28
	Tutorial									
	Lab									
Wednesday	Lecture	EEP55C24 - AP2.04	EEP55C24 - AP2.04	CS7GV5 - 4.09	EE5M02 - AP2.02		CS7NS2 - 1.07 LLOYD	CS7DS2 - LB08	ME5E3 - PBENG	ME5E3 - PBENG CS7NS5 - LB04
	Tutorial									
	Lab									
Thursday	Lecture		CS7IS2 - LB01		EEP55C24 - AP2.04	EEP55C24 - M17	EEP55C23 - PBENG	EEP55C23 - PBENG CS7CS3 - LB01	EEP55C25 - AP2.28 CS7CS3 - LB01	EEP55C25 - AP2.28 CS7CS3 - LB01
	Tutorial									
	Lab									
Friday	Lecture	EE5M01 AP2.28	EE5M01 - AP2.28	EE5C01 - AP2.28 CS7NS6 - 1.07 LLOYD	EE5C01 - AP2.28	CS7NS2 - 1.07 LLOYD	CS7IS2 - LB08			MECHLB
	Tutorial									
	Lab									

LECTURES/Demos

NUKE (weeks 1,2,3), Assignment time weeks 4-6
Compression Lab week 6, Assigment time weeks 9-12

ClassTests/Industry Talks

Some speakers in CA and NZ so we'll have to get creative

		Week											
		1: Jan 24th	2 : Jan 31st	3: Feb 7th	4: Feb 14th	5: Feb 21st	6: Feb 28th	7: 7th Mar	8: 14 Mar	9: 21st Mar	10: 28 Mar	11: Apr 4	12: Apr 11
		Segmentation and Perception		Motion and Video		Denoising and Colour and Engineering Standards			Compression	Adaptive Streaming	Adaptive Streaming	DNNs for Compression	Exam Review
Monday 12 - 13:00	**Lecture**	Intro	Perception	Motion 1	Motion 2	Denoising	Motion		Intro and Compression	Cancel			
Monday 16 - 17:00	**Lecture**	Bayes	Perception	Motion	DNN	**Motion**	Motion		Compression	ABR DASH			
												Ioannis Talk	
Tuesday 15-17	**Lecture**	Keying	Keying	Bayes NUKE	MotionNUKE	NUKE	Perception		Compresson				
	Labs	NUKE	NUKE	Ass	Ass	Ass							
Friday 11-13:00	**Lecture**	Bayes	Colour		DNN	Denoising	Perception		RD Curves Lab	RD Curves Lab	ABR Bitrate Ladder Lab	ABR Bitrate Ladder Lab	ABR Bitrate Ladder Lab
	Labs	NUKE	NUKE	Ass	Ass	Ass							

Keynotes

From last year

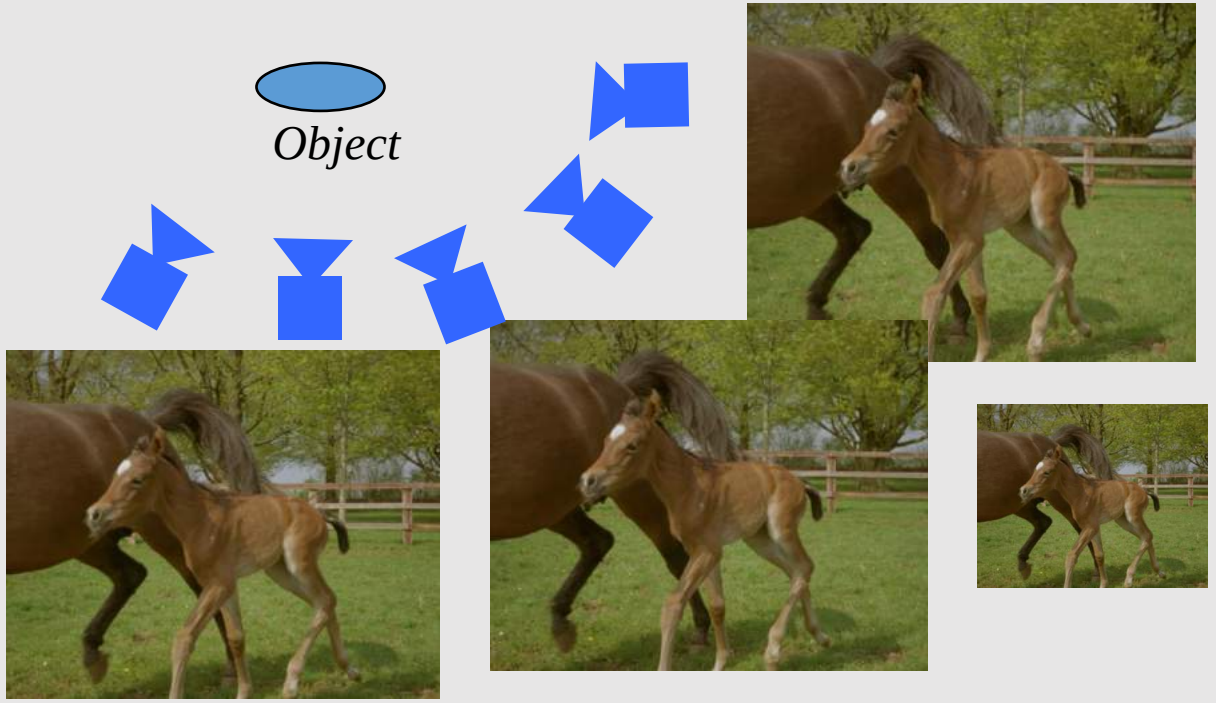
- Simon Robinson (Academy Award Winner from the Foundry, London)
- Peter Hillman (Academy Award winner from Weta Digital, New Zealand)
- Peyman Milanfar (R&D Lead for Pixel Cameraphone at Google, California)
- Marta Mrak (BBC R&D, London)

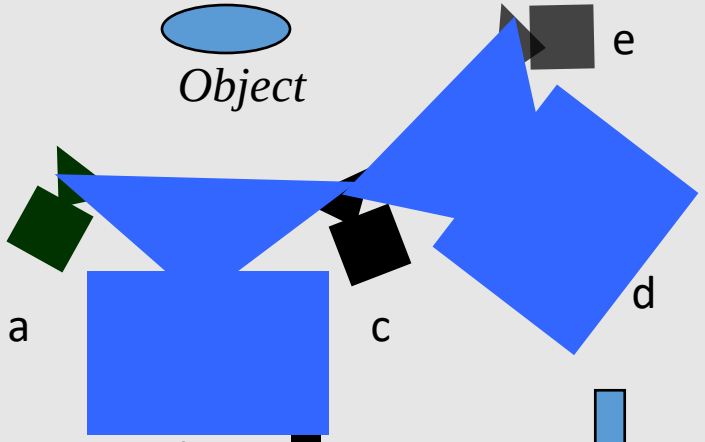
TBC

Ioannis Katsavounidis (Video Infra Lead at Facebook)

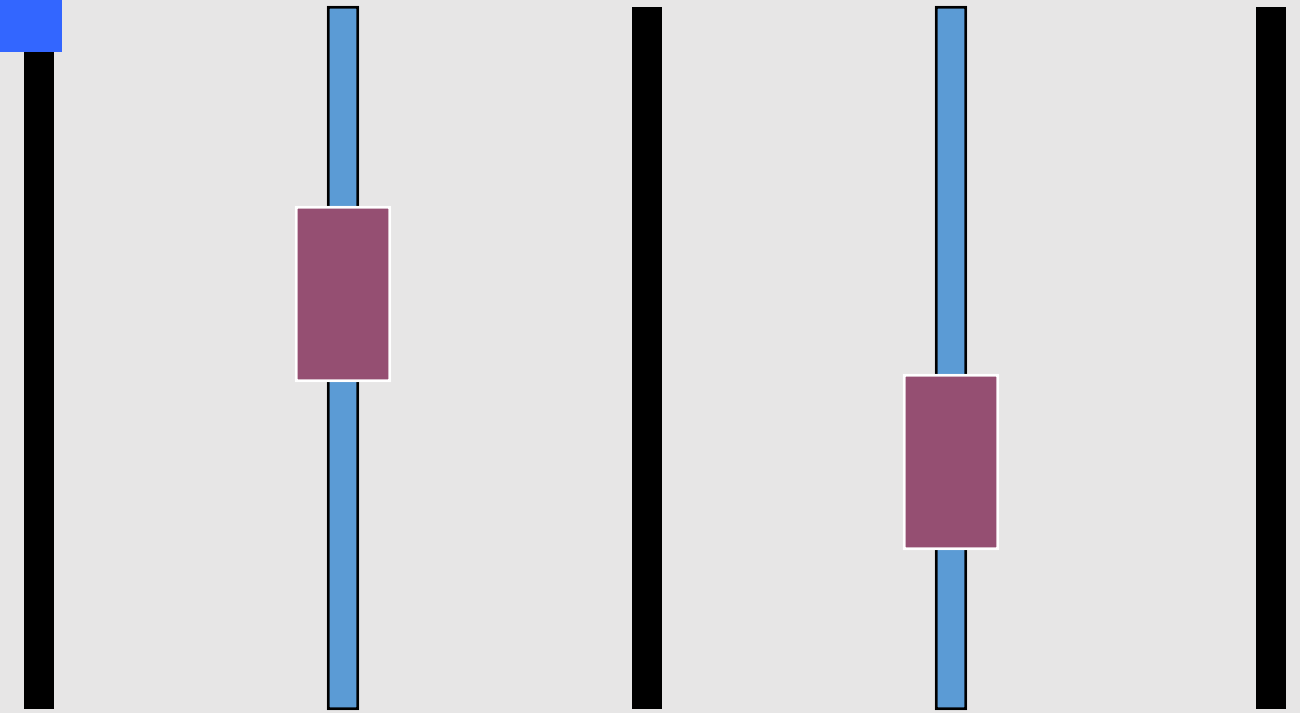
Paul Wilkins (Google/Chrome)

Bullet Time





Cameras too big to be close enough!



A? b C? d E?

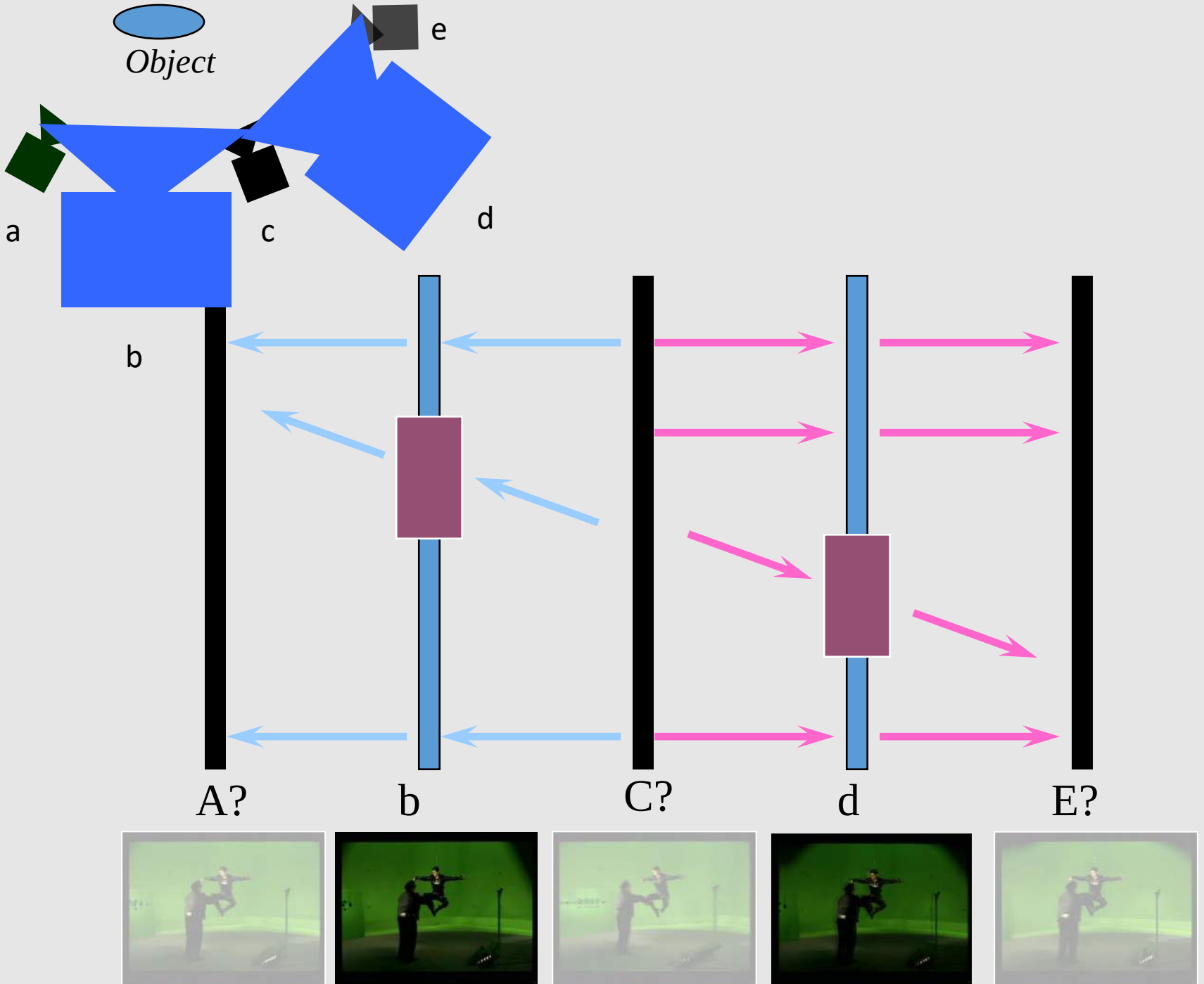
Thinking about “inbetweening”

Current

Next

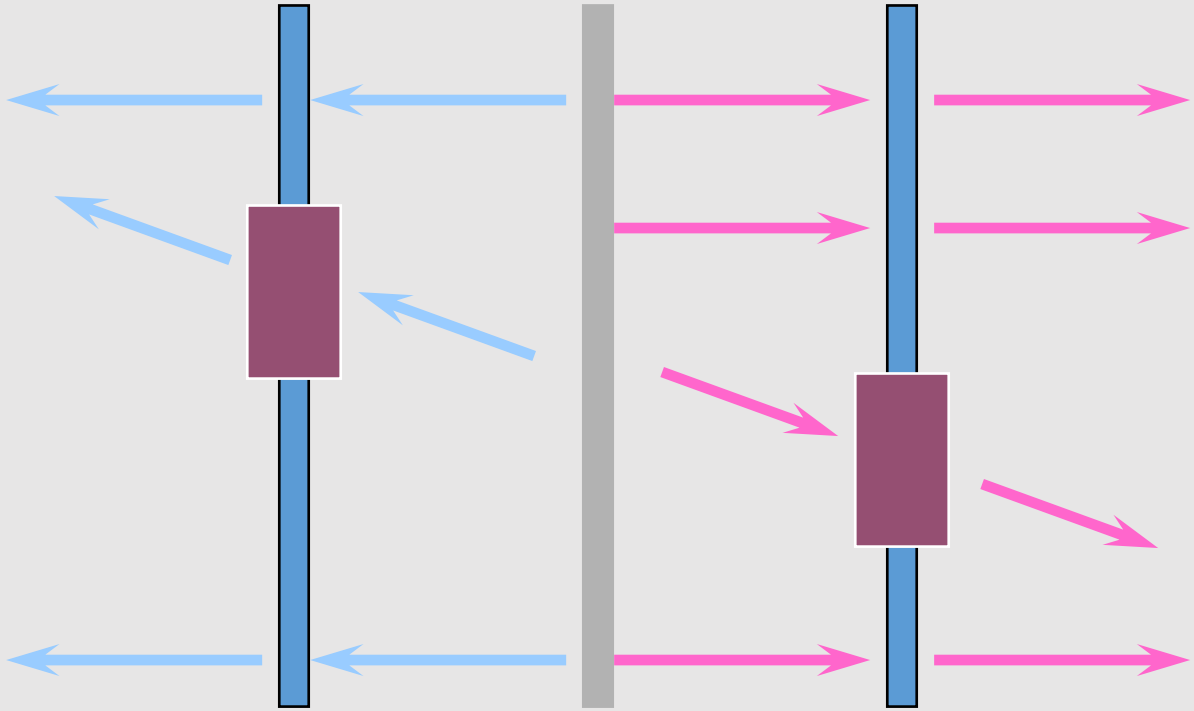
Blurring due to motion

(Current+Next)/2


Object
e
a
c
d
b
A?
b
C?
d
E?

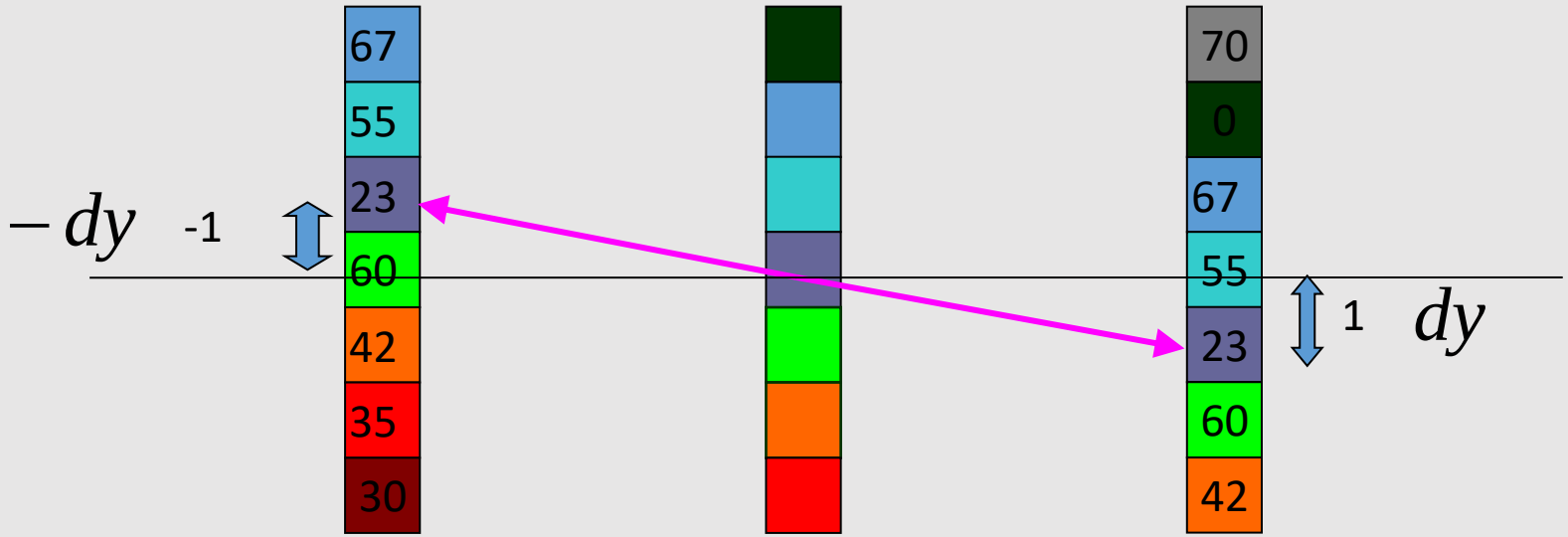
Some observations that help

The cameras always cause smooth movement



When things move
They don’t change colour much

Bullet Time : Mathematical modelling

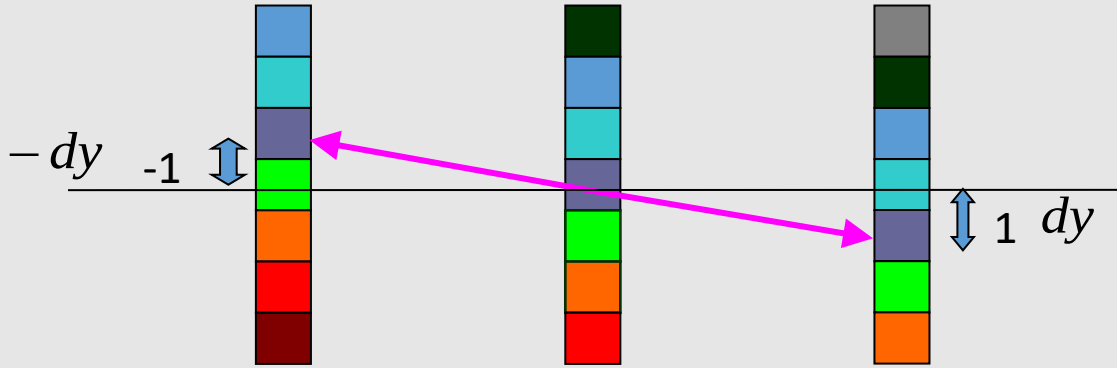


$$I_{n-1}(k-dy) = I_{n+1}(k+dy)$$

Bullet Time : How to solve for dy

$$I_{n-1}(k-dy) = I_{n+1}(k+dy)$$

$$\Rightarrow I_{n-1}(k-dy) - I_{n+1}(k+dy) = 0$$



Tricky because we have no analytic function for *I()*

So change this into an "optimisation problem"

Choose *dy* such that it makes $(I_{n-1}(k-dy) - I_{n+1}(k+dy))^2$ as small as possible

Minimise $(I_{n-1}(k-dy) - I_{n+1}(k+dy))^2$ wrt dy

Bullet Time : The Equation is actually 2D!

$$I_{n-1}(h-dx,k-dy)=I_{n+1}(h+dx,k+dy)$$

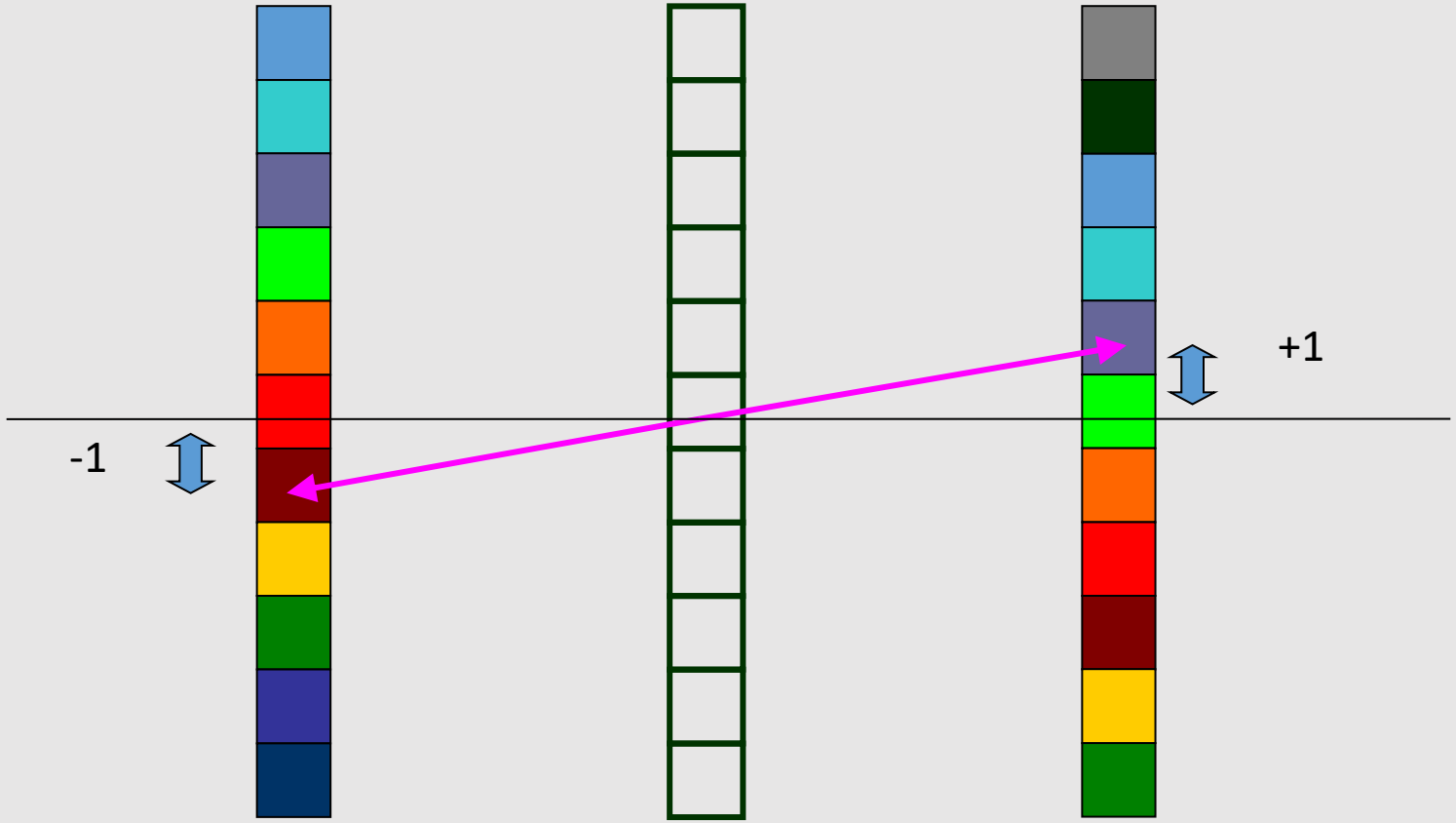
$$\text{Minimise}\,(I_{n-1}(h-dx,k-dy)-I_{n+1}(h+dx,k+dy))^2\ \text{wrt}\,(dx,dy)$$

Oh crap.
There is no analytic solution. We don't have an explicit form for I(x,y)
And the solution is HUGE.
There is a dx and dy for EVERY PIXEL in EVERY frame!
4 Million Variables!

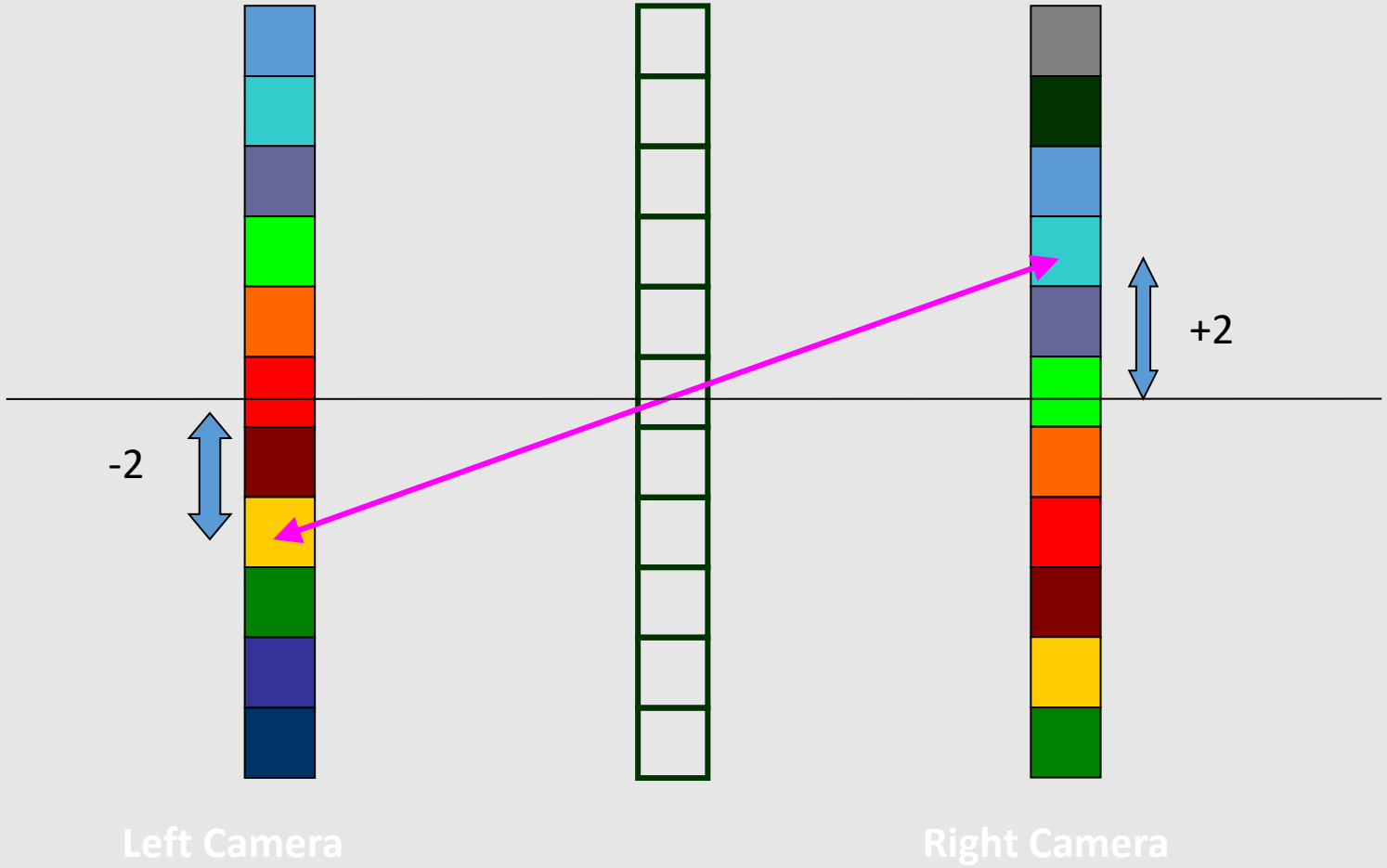
Brute force numerical solution : examine subset of possible pixel pairs and pick the pair which gives least “squared error”

$$E(dy) = (I_{n-1}(k - dy) - I_{n+1}(k + dy))^2$$

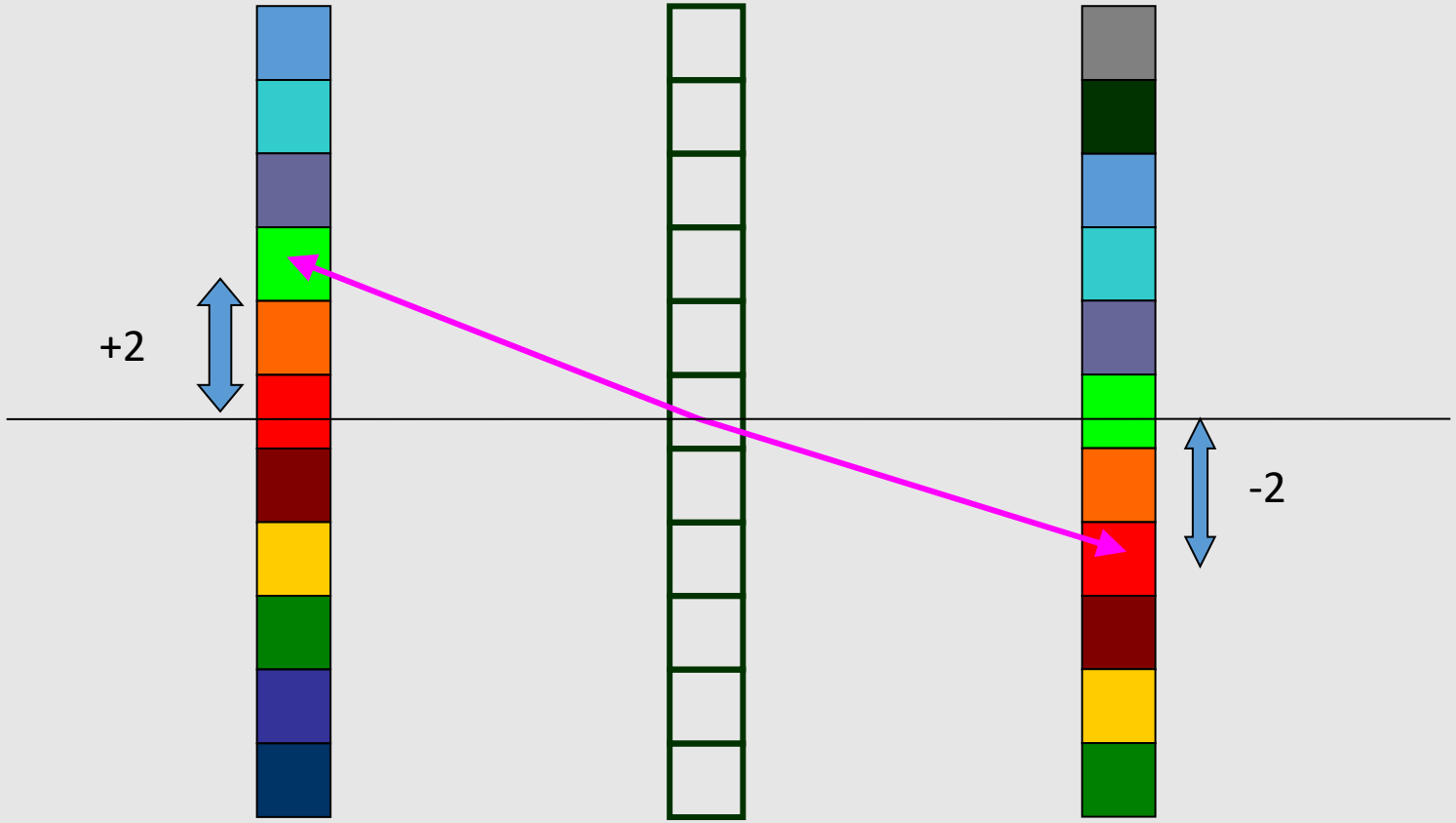
$$E(dy = 1) = 27$$



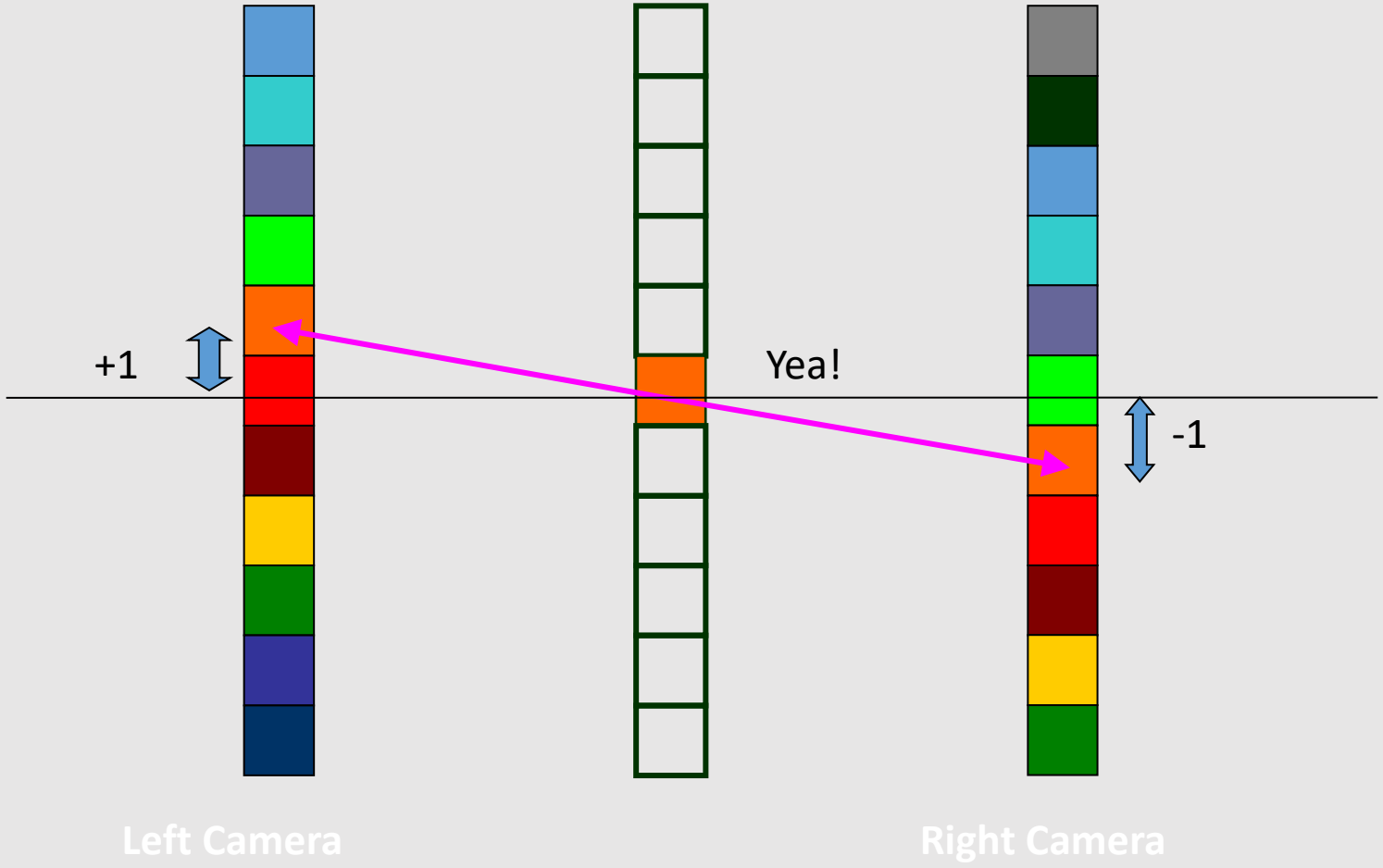
$$E(dy=1)=27$$
$$E(dy=2)=53.2$$

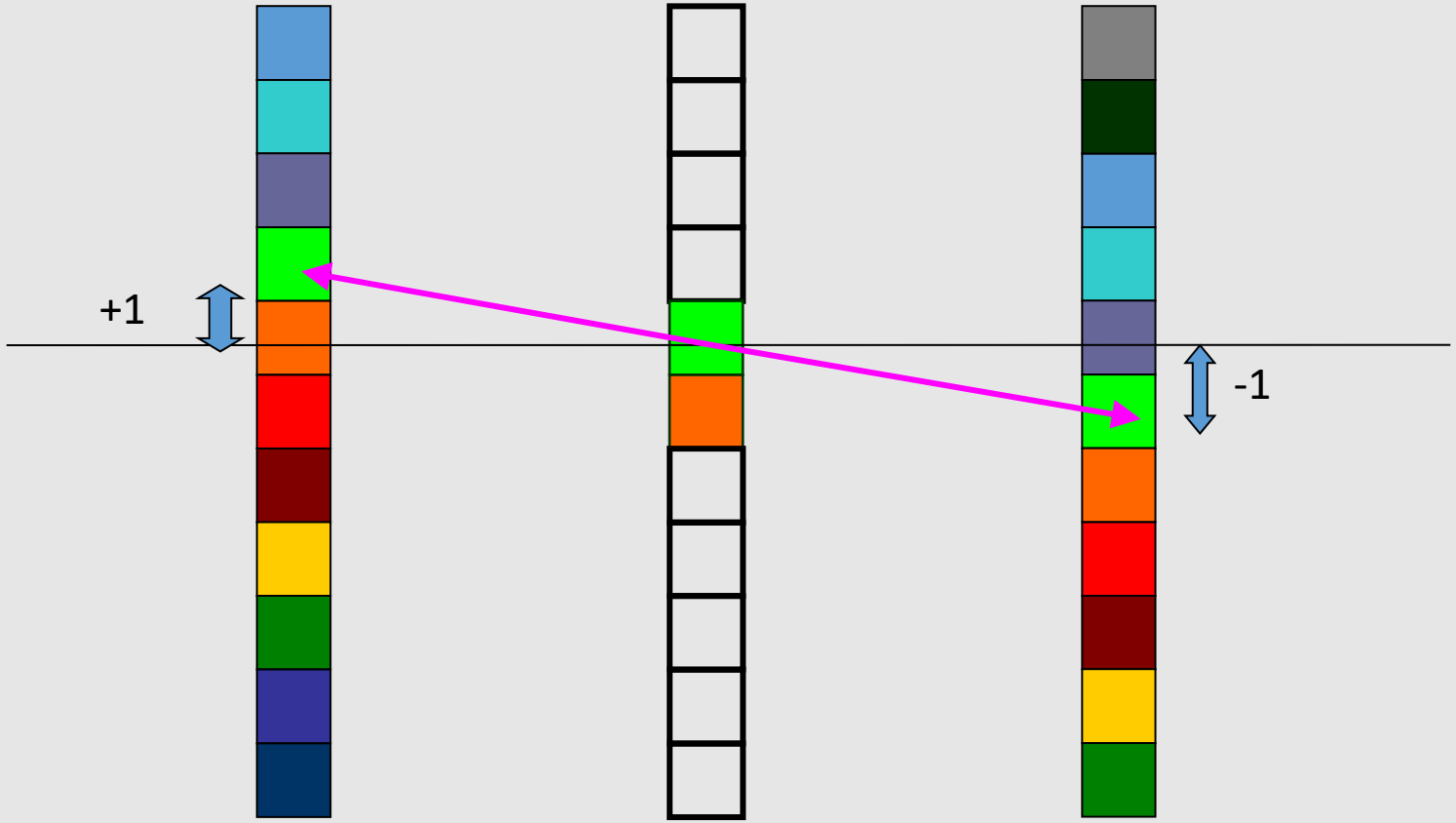


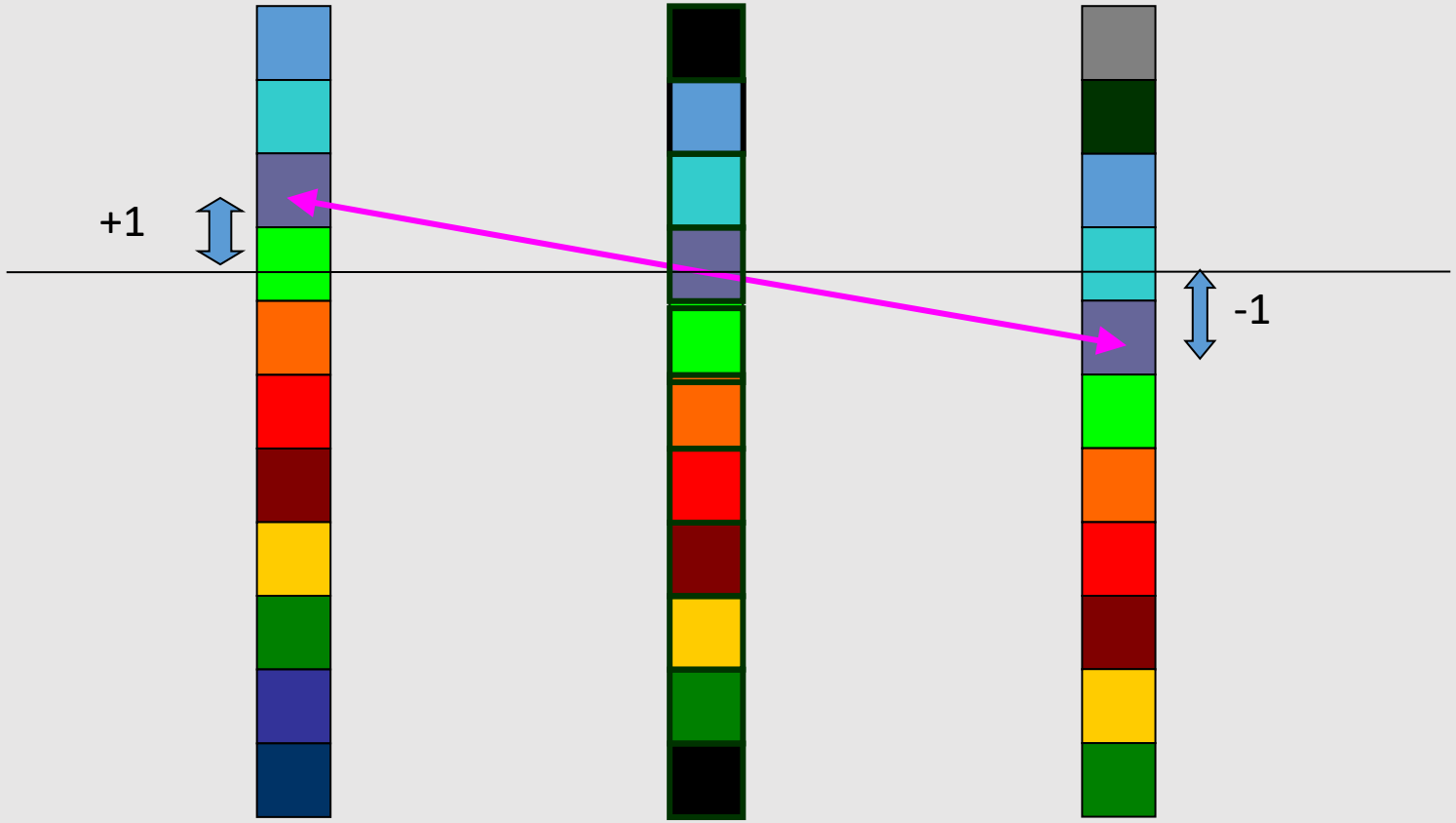
$$E(dy=1)=27$$
$$E(dy=2)=53.2$$
$$E(dy=-2)=10.2$$



$$E(dy=1)=27$$
$$E(dy=2)=53.2$$
$$E(dy=-2)=10.2$$
$$E(dy=-1)=1.2$$




+1
-1


+1
-1

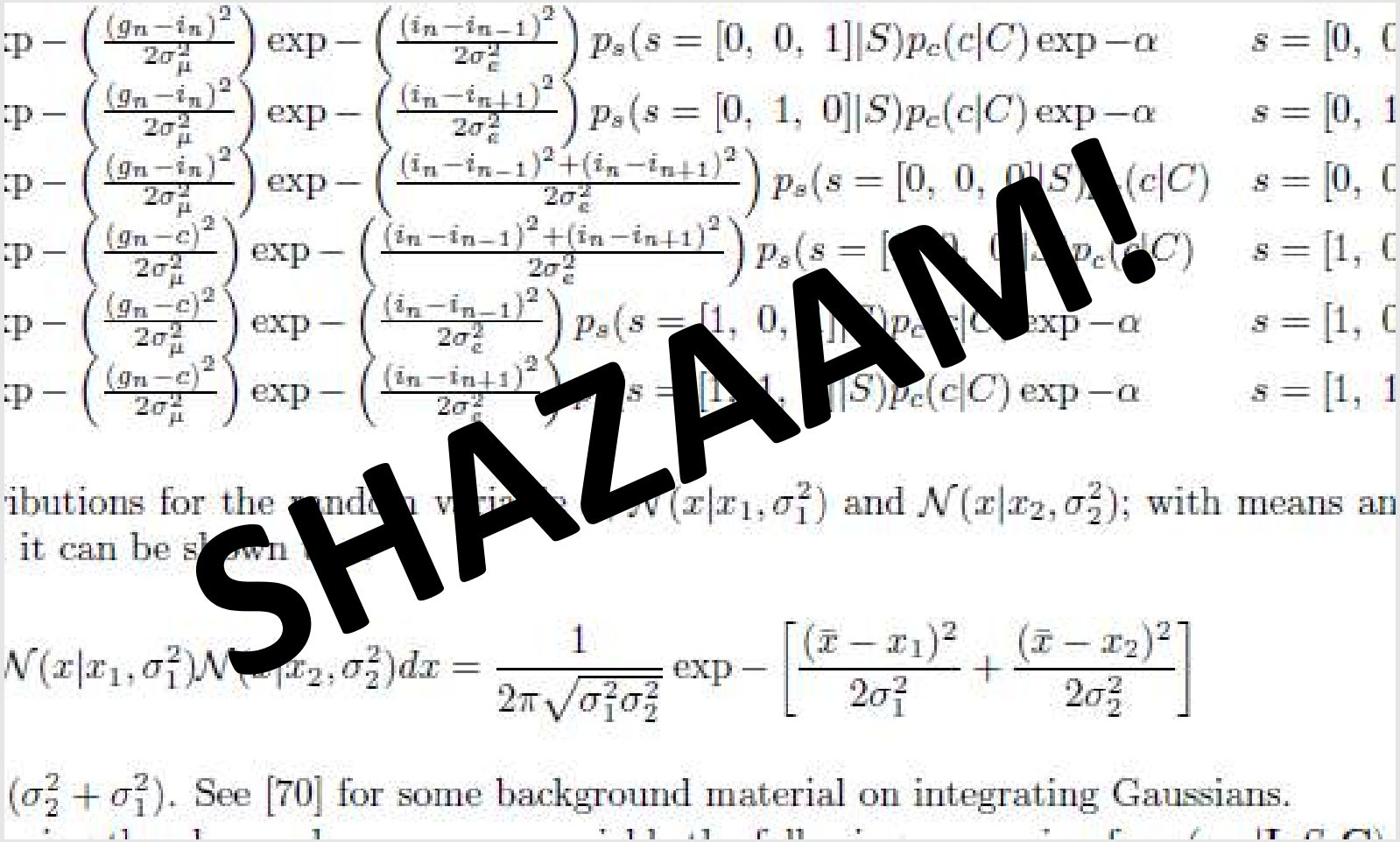
What about implementation?

```
function [new_frame] = inbetween(left, right, w)
  %Inputs are left and right vectors of pixels, and w the search space
  rows = length(left);
  new_frame = zeros(size(left));
    for k = w + 1 : rows - w,
      error = zeros(w*2+1,1);
      %At this pixel location "k", calculate the error
      %associated with every possible offset dy
      for dy = -w : w,
        error(dy + w + 1) = (left(k - dy) - right(k + dy))^2;
      end;
     %Select the dy that minimised the error
     [y, index] = min(error);
     estimated_dy = index - w - 1;
     %Use it to calculate an interpolated value
     new_frame(k) = (left(k - estimated_dy) + right(k + estimated_dy))/2;
   end;
```

Actually this simple “algorithm” has issues

- Search space is “integer” but the motion is “fractional”
- We need to work in colour i.e. 3 pixels at each location not one
- There is noise in real signals .. So the pixel differences will be “noisy”
  - That leads to random motion estimates
  - Which leads to “weirdly distorted” in-betweens.
- No guarantee that the motion estimates are “smooth enough”
- In real life sometimes you can’t find a match because objects move behind or in front of each other. So the “mathematical model” is not right everywhere.
  - That leads to objects sticking to background
- It is too dirt slow!

So we need better modelling etc etc




0.7
0.7
x4 Repeat Frames
x4 MotionReTime


Goro@Welsh corgi