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Data-driven & Model-driven Methods

and their use in computer vision

Xiaohao Cai

University of Southampton UK

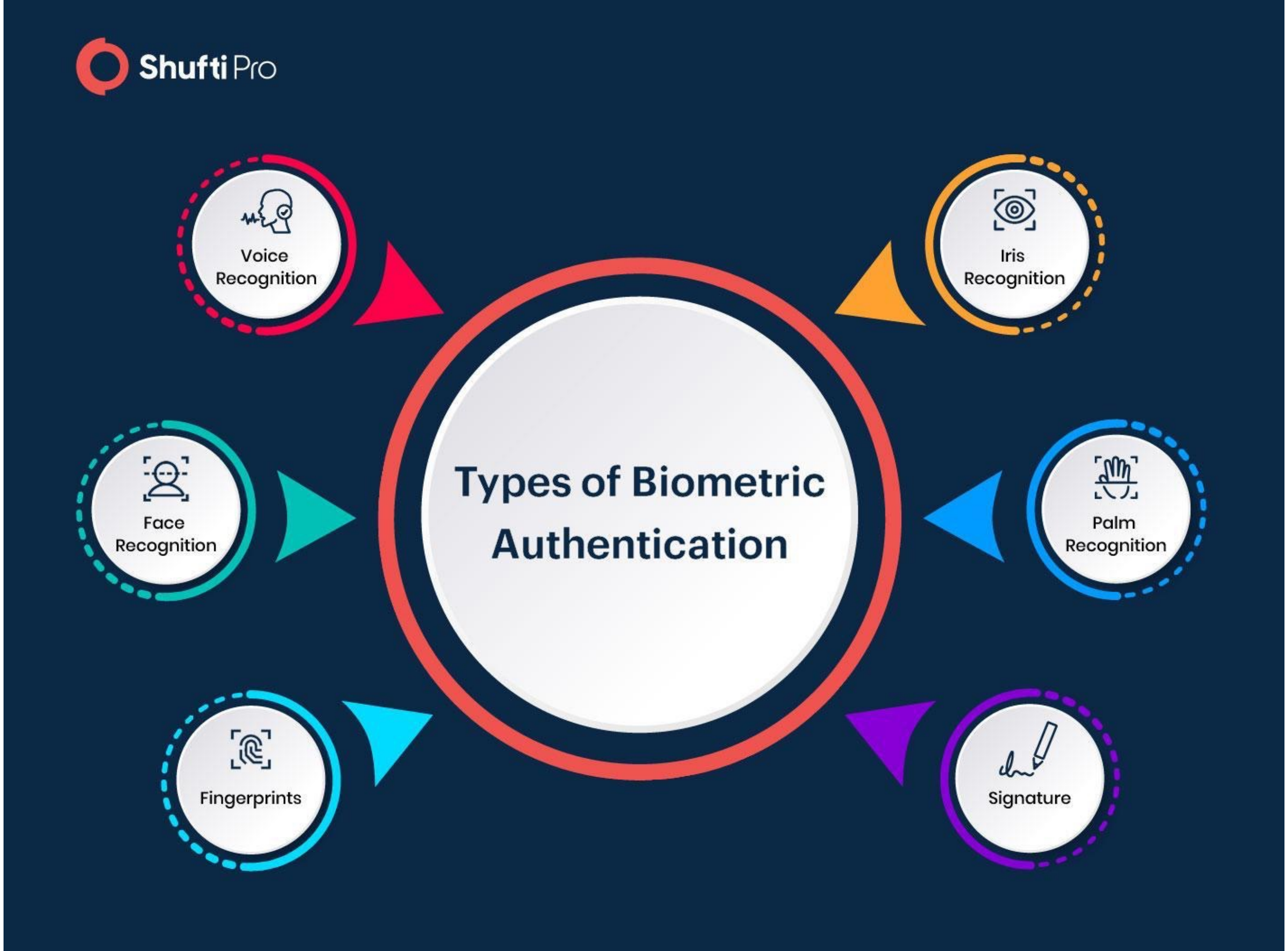
COMP3204 Computer Vision

What are their pros and cons?

Credit Prof. Mark Nixon

Content

1. Biometrics account for a large portion in computer vision
2. Some data-driven and model-driven methods in computer vision



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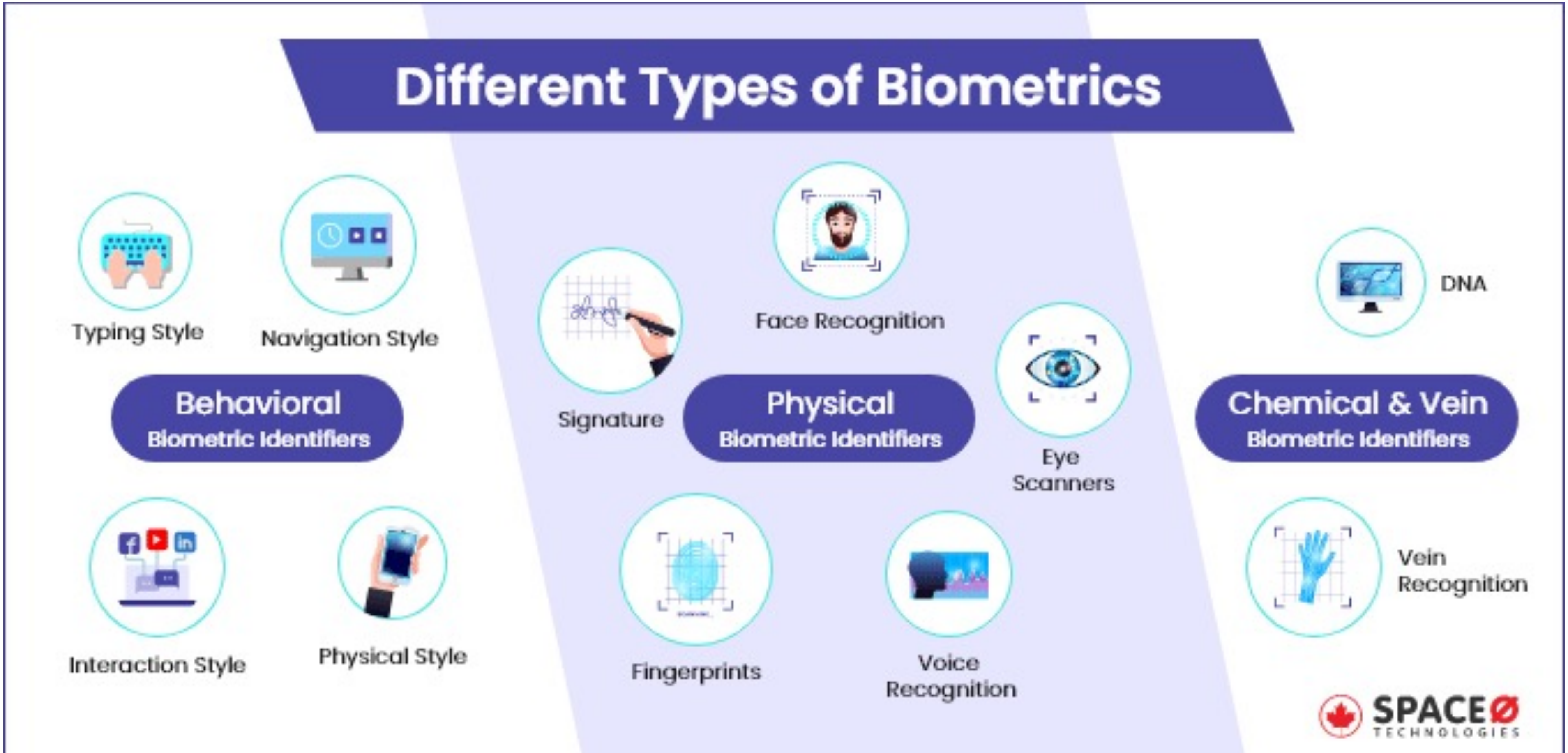
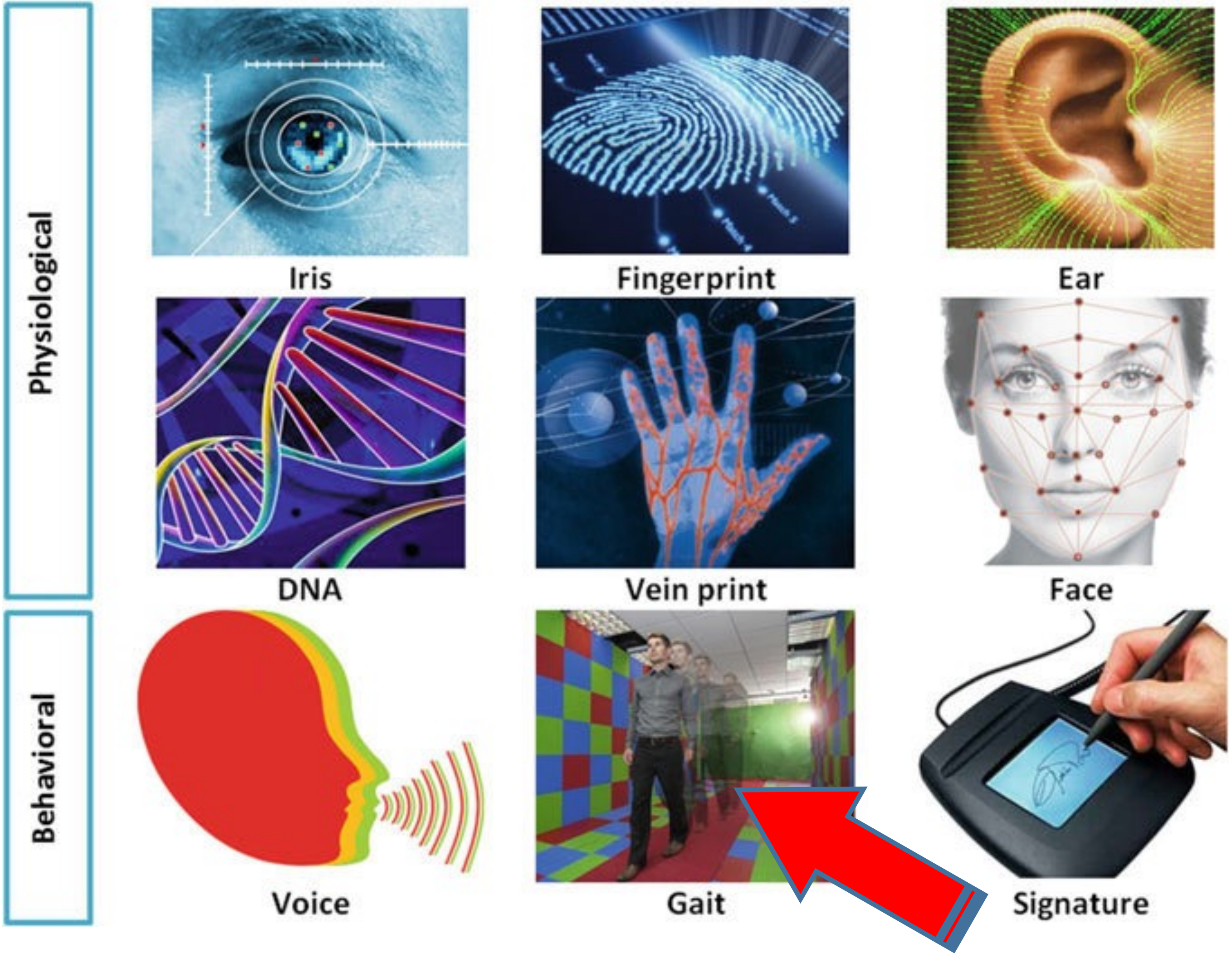


https://www.spaceo.ca/biometrics-authentication-types-technology-trends/


Physiological
Behavioral
Iris
Fingerprint
Ear
DNA
Vein print
Face
Voice
Gait
Signature

Gait biometrics

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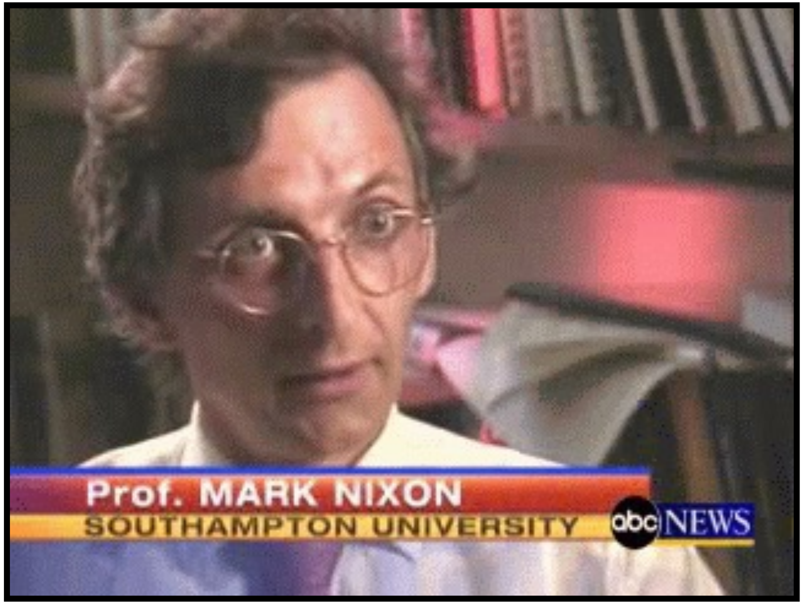

Identifying people by their gait

As a biometric, gait is available at a distance when other biometrics are obscured or at too low resolution

ABC News, July 13 2006

Many gait representations possible

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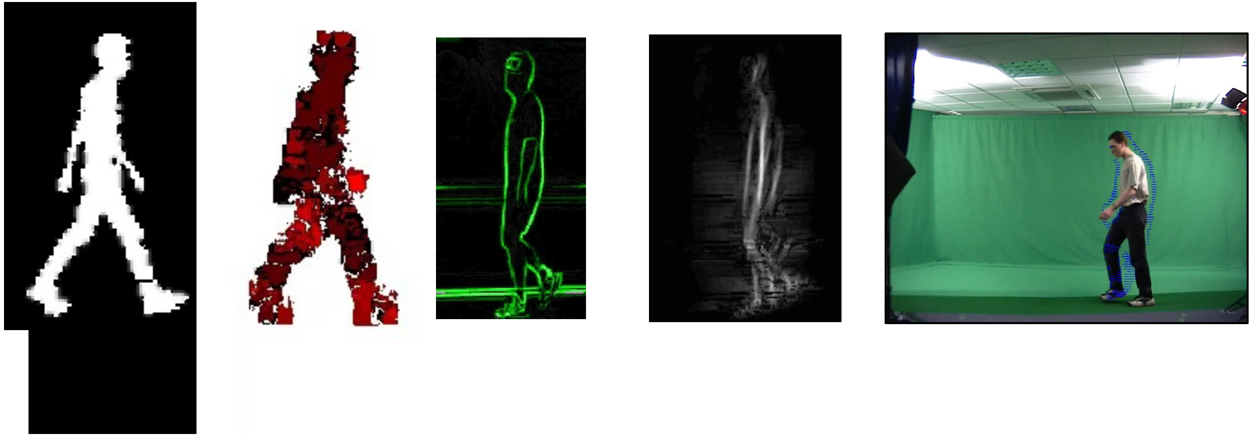
Recognising people from the motion of the whole body



silhouette flow edges symmetry acceleration

MS Nixon, T Tan, R Chellappa, Springer, 2005

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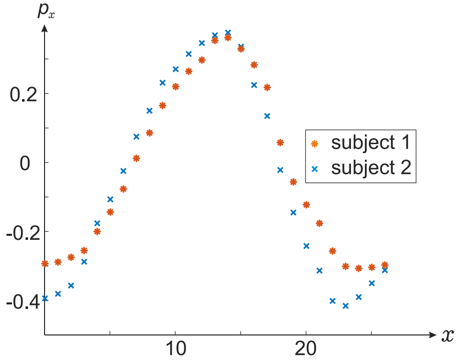
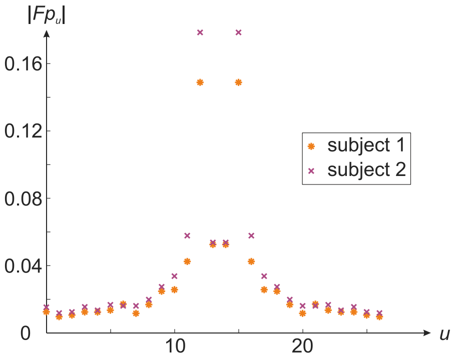
Model-based recognition

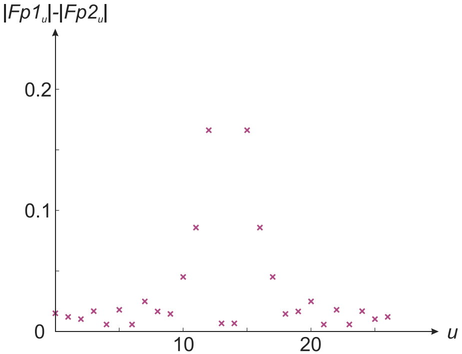




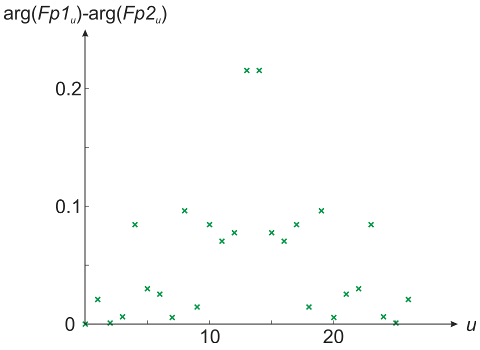
Inclination of thigh



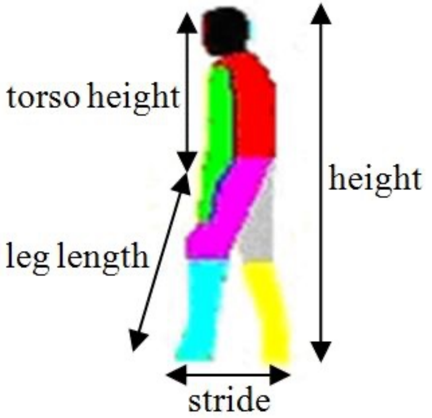
Magnitude of DFT



Difference between magnitude



Difference between phase



Other models are possible

D Cunado, MS Nixon, JN Carter, Proc. AVBPA, 1997

Hand crafted then; deep learning now

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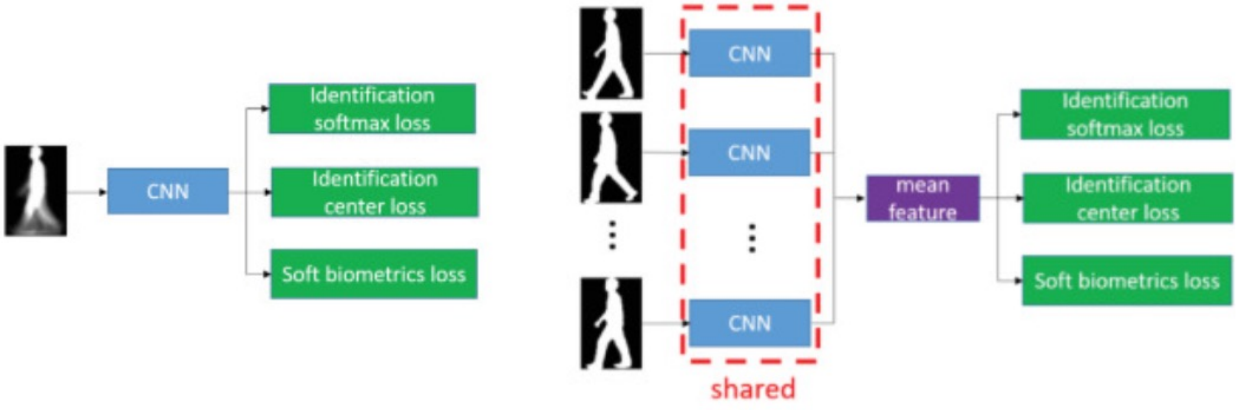

(a) Image level fusion (b) Feature level fusion

(c) Network architecture

Y Zhang, Y Huang, L Wang, S Yu, *Pattern Recognition*, 2019

Recent works - Gait

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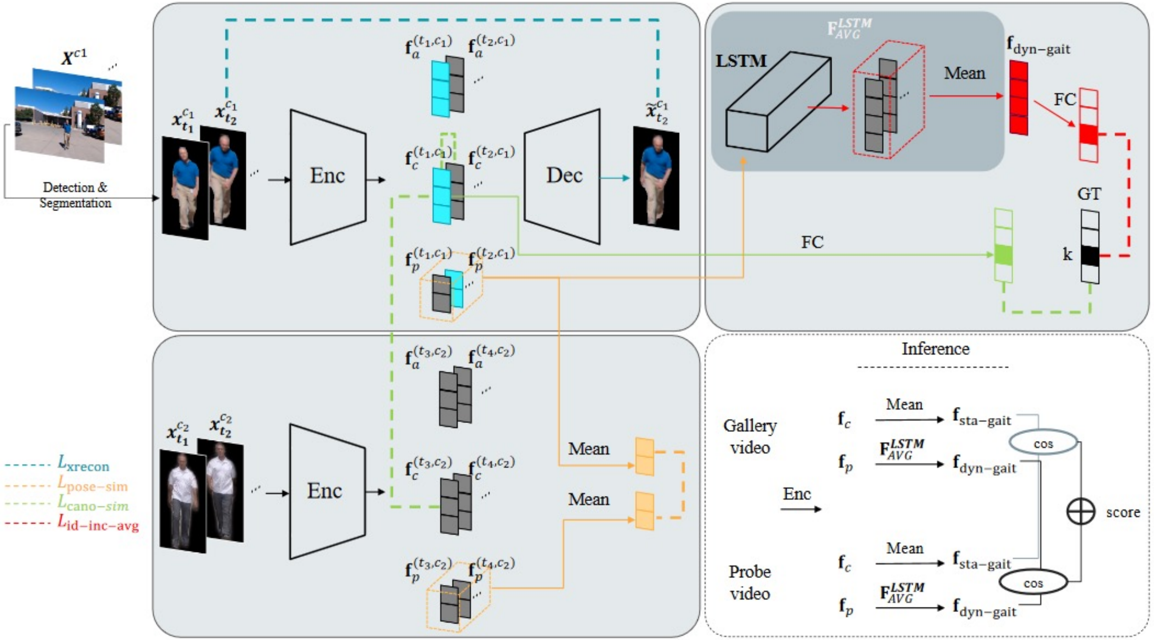
Fig. 1. Samples from the KinGaitWild dataset



SE Bekhouche, A Chergui, A Hadid..., ICIP 2020

Z Zhang, L Tran, F Liu , X Liu, IEEE TPAMI 2019

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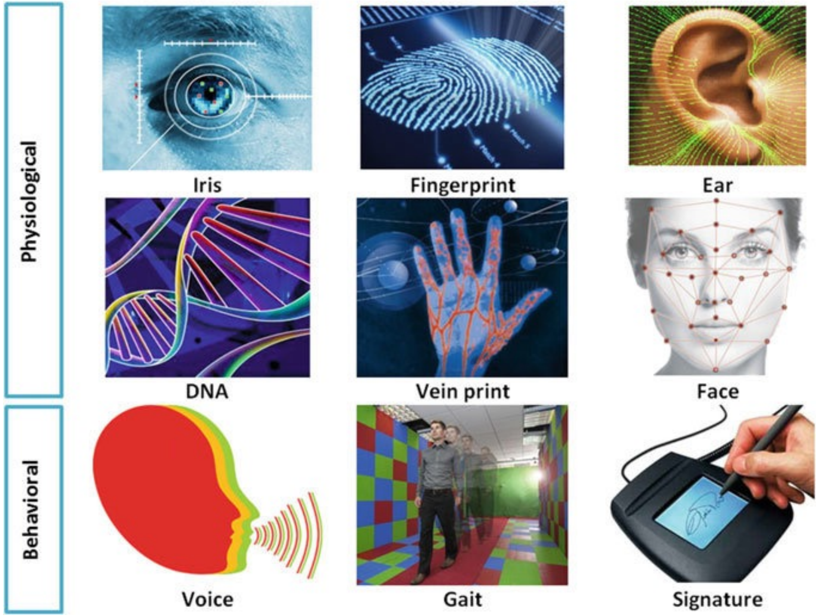

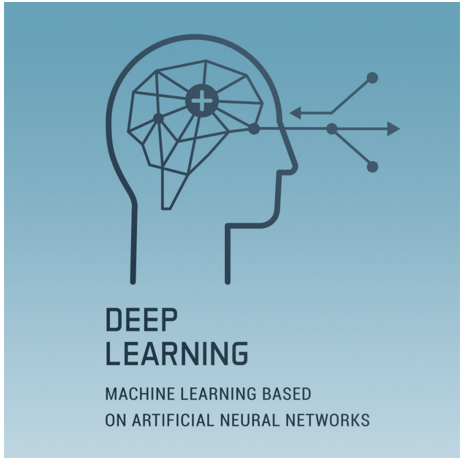

IMAGE COLORING

Before After

IMAGE NOISE REDUCTION

Before After

and many more …

"DATA IS THE NEW GOLD"

https://www.civilsdaily.com/burning-issue-data-the-new-gold/

Gait biometrics databases

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Laboratory

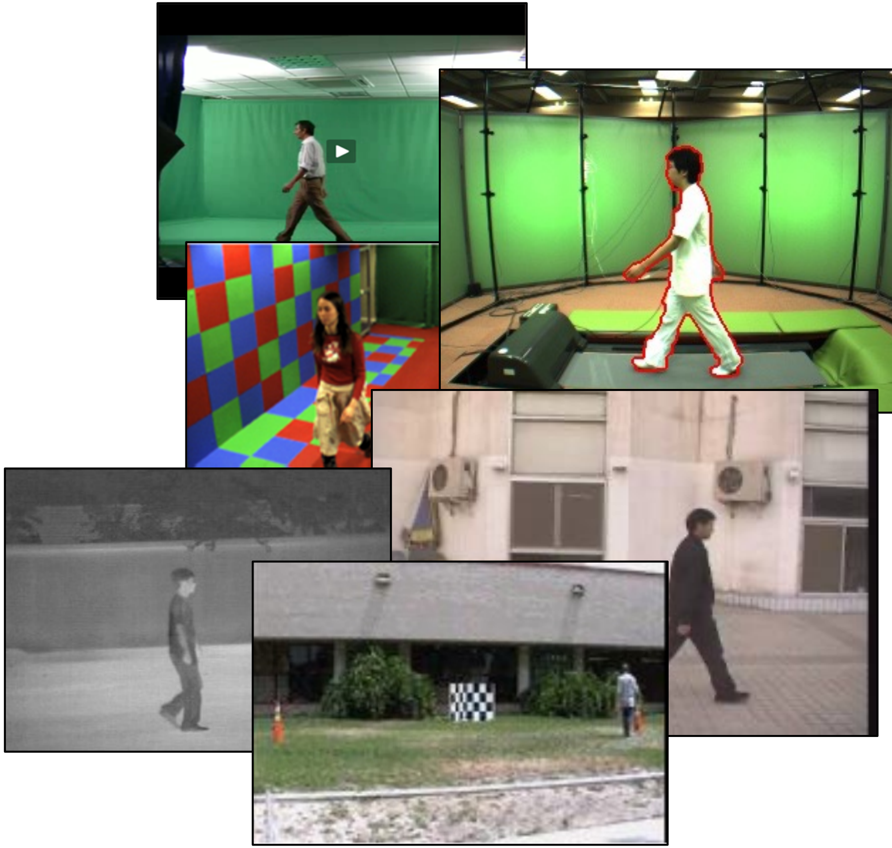
- Southampton 3D and 2D
- CASIA (+ multiview, thermal)
- Osaka OU-ISIR (+ multiview)

'Real' World

- HumanID
- Southampton
- CASIA

+ accelerometer, footfall, medical

M Okumura, Y Makihara, Y Yagi, IEEE TIFS 2012



What changes regarding datasets?

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Many covariates can affect walking style

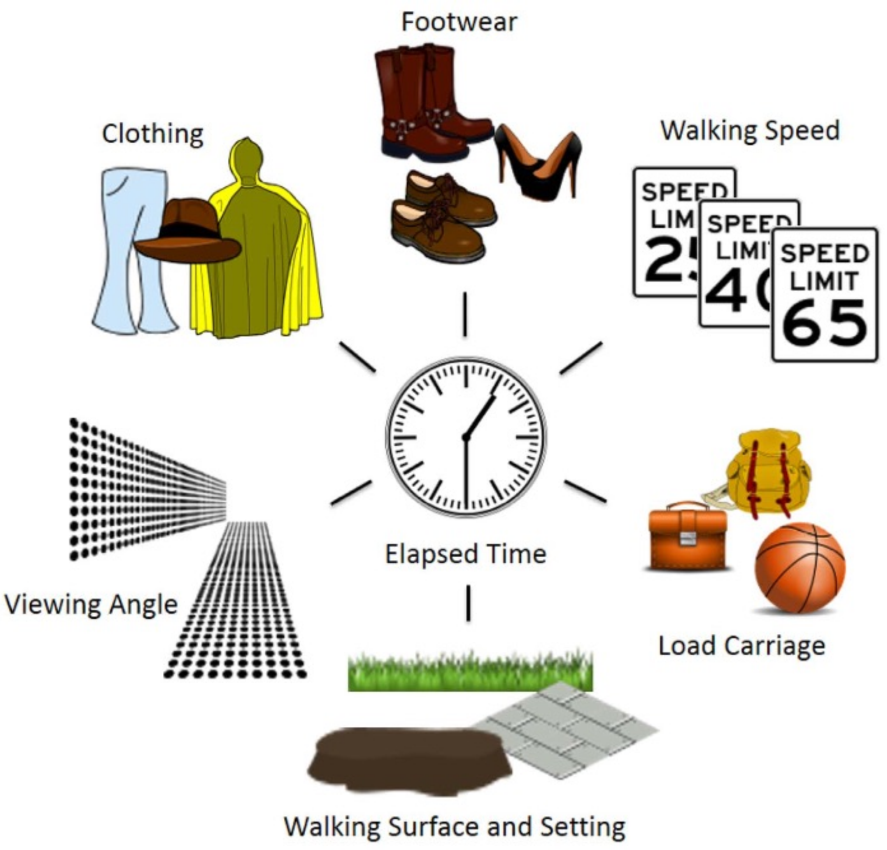
.... + health, drugs, mood ...

Domain shift

Class imbalance

Noisy annotation

and more …



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Medical imaging with AI

Microsoft | Microsoft News Centre UK   Education   Security   Smart Tech   Digital Skills   News and Stories   Press Tools

A Microsoft AI tool is helping to speed up cancer treatment – and Addenbrooke's will be the first hospital in the world to use it

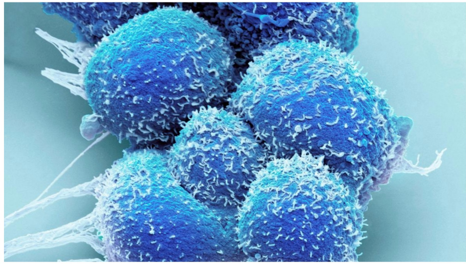
December 9, 2020 | Microsoft reporter

THE TIMES   Today's sections   Past six days   Explore   Times Radio   Log in

Inner Eye AI identifies tumours to speed up treatment of cancer

Katie Gibbons

Monday January 11 2021, 12.01am, The Times



The Inner Eye software is the result of an eight-year project with Microsoft and Addenbrooke's hospital
ALAMY

A hospital in Cambridge is the first to use artificial intelligence technology developed by Microsoft to treat cancer patients faster, helping to cut the treatment backlog and save lives.

https://news.microsoft.com/en-gb/2020/12/09/a-microsoft-ai-tool-is-helping-to-speed-up-cancer-treatment-and-addenbrookes-will-be-the-first-hospital-in-the-world-to-use-it/

Medical imaging with AI

https://www.bbc.co.uk/news/uk-scotland-56734407

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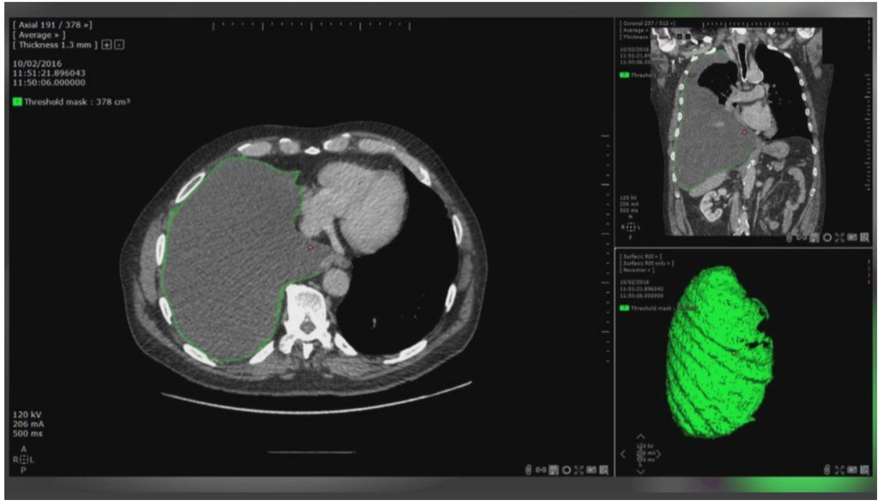
AI technology used to track asbestos cancer tumours

By Laura Goodwin
BBC Scotland Innovations Correspondent

2 days ago



thebmj

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Research

Use of artifici

programmes:

BMJ 2021 ; 374 d
Cite this as: *BMJ* 2(

Article | Rel

Karoline Freeman
Daniel Todkill , cl
Aileen Clarke, profess
llow [1],

Author affiliation

Correspondence to

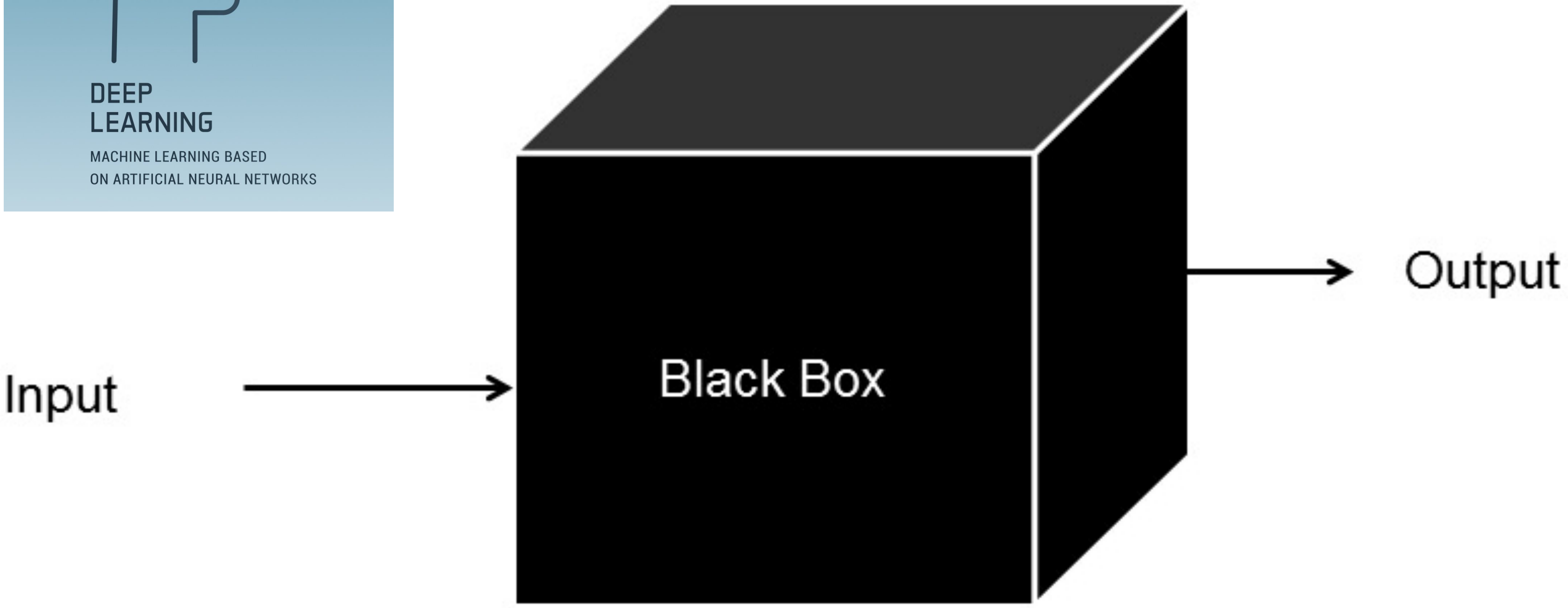
Accepted 21 July 2

Abstract

Conclusions

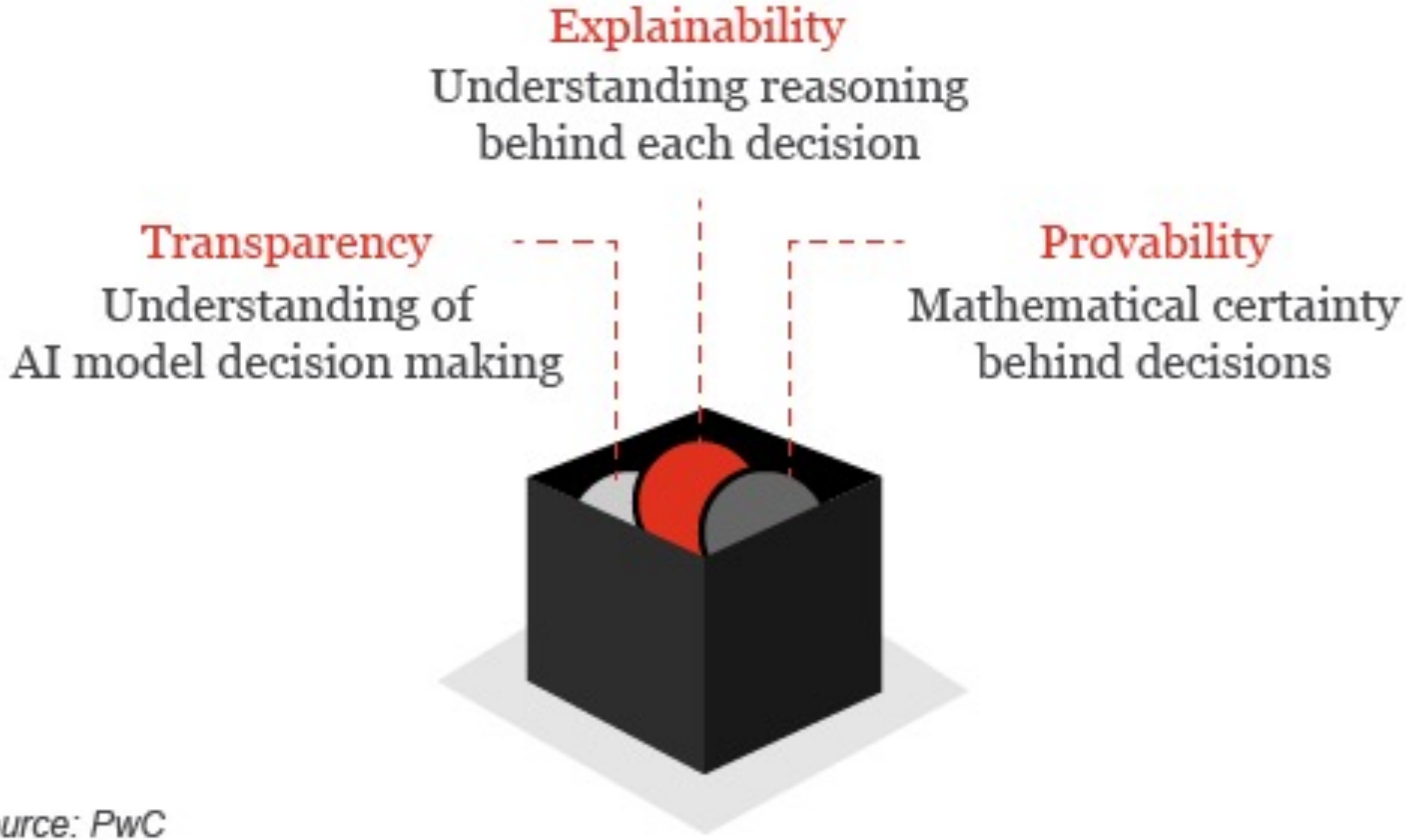
Current evidence on the use of AI systems in breast cancer screening is a long way from having the quality and quantity required for its implementation into clinical practice. Well designed comparative test accuracy studies, randomised controlled trials, and cohort studies in large screening populations are needed which evaluate commercially available AI systems in combination with radiologists. Such studies will enable an

https://www.bmj.com/content/374/bmj.n1872



Internal behavior of the code is unknown

What it means to look inside the black box



Source: PwC

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POST

Research Briefing

Interpretable machine learning

Published Tuesday, 06 October, 2020

POSTnote | Crime and justice | Digital tech | Health and social care | Transport and infrastructure | Research

Lorna Christie

Machine learning (ML, a type of artificial intelligence) is increasingly being used to support decision making in a variety of applications including recruitment and clinical diagnoses. While ML has many advantages, there are concerns that in some cases it may not be possible to explain
This POSTnote gives an overview of ML and its role in decision-
understanding how a complex ML system has reached its outp
making ML easier to interpret. It also gives a brief overview of
systems more accountable.

In 2018, the Lords Committee on AI called the development of AI systems that are "intelligible to developers, users and regulators". It recommended that an AI system that could have a substantial impact on an individual's life should not be used unless it can produce an explanation of its decisions.[4] In a


KEEP
CALM
AND
USE DATA
WISELY

Model-driven Methods

Active Contours

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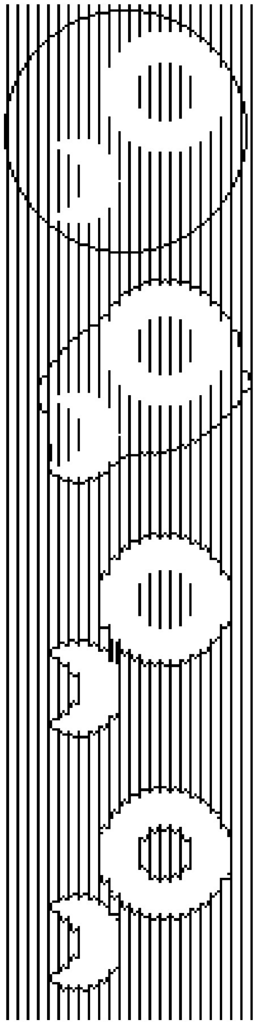
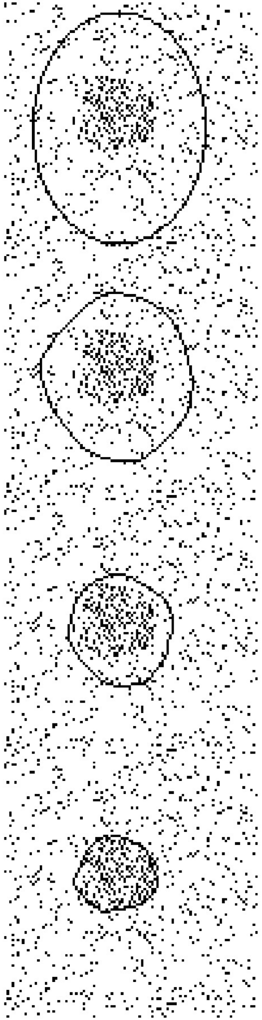
International Journal of Computer Vision, 321–331 (1988)
© 1987 Kluwer Academic Publishers, Boston, Manufactured in The Netherlands

Snakes: Active Contour Models

MICHAEL KASS, ANDREW WITKIN, and DEMETRI TERZOPOULOS
Schlumberger Palo Alto Research, 3340 Hillview Ave., Palo Alto, CA 94304

[credit: wikipedia]





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266 IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 10, NO. 2, FEBRUARY 2001

Active Contours Without Edges

Tony F. Chan, *Member, IEEE,* and Luminita A. Vese

***Abstract*—In this paper, we propose a new model for active contours to detect objects in a given image, based on techniques of curve evolution, Mumford–Shah functional for segmentation and level sets. Our model can detect objects whose boundaries are not necessarily defined by gradient. We minimize an energy which can be seen as a particular case of the minimal partition problem. In the level set formulation, the problem becomes a "mean-curvature flow"-like evolving the active contour, which will stop on the desired boundary. However, the stopping term does not depend on the gradient of the image, as in the classical active contour models, but is instead related to a particular segmentation of the image. We will give a numerical algorithm using finite differences. Finally, we will present various experimental results and in particular some**

the image (the external energy). Observe that, by minimizing the energy (1), we are trying to locate the curve at the points of maxima $|\nabla u_0|$, acting as an edge-detector, while keeping a smoothness in the curve (object boundary).

A general edge-detector can be defined by a positive and decreasing function g, depending on the gradient of the image u_0, such that

$$\lim_{z\to\infty} g(z) = 0.$$

For instance

Models

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Models proposed in our work, e.g.:

- $\min_x \left\{ \frac{\lambda}{2} \|y - \mathcal{A}x\|_2^2 + \|\mathcal{W}x\|_1 \right\}$
- $\min_g \left\{ \frac{\lambda}{2} \|f - \mathcal{A}g\|_2^2 + \frac{\mu}{2} \|\nabla g\|_2^2 + \|\nabla g\|_1 \right\}$
- $\mu\Phi(f, \mathcal{A}g) + \lambda\Psi(g, u_i, c_i) + \sum_{i=1}^{K} \int_\Omega |\nabla u_i|$
  $\text{s.t.} \quad \sum_{i=1}^{K} u_i(x) = 1, u_i(x) \in \{0, 1\}$
- $\min_{u \in S} \left\{ \frac{1}{2} \|f - \mathcal{B}u\|_2^2 + \lambda \|\nabla u\|_0 \right\}$
- $\min_\psi \left\{ D[T(\psi), R] + \alpha \|\Delta\psi\|_2^2 \right\}$

Convex optimisation algorithms

- ADMM
- Primal-dual
- Split-Bregman
- Augmented Lagrangian

Sparse regularizations

- $\|\cdot\|_0$, $\|\cdot\|_1$, $\|\cdot\|_2$
- with $\nabla, \Delta, \mathcal{W}$
- $\mathcal{W}$: Wavelet transform

T-ROF *(Thresholded-ROF)*

[SISC, '19; EMMCVPR, '13]
X. Cai, R. Chan, C.-B. Schönlieb
G. Steidl, T. Zeng

Image Restoration

ROF model
(1992, citation > 15,700)

thresholding →

Image Segmentation

Chan-Vese model
(2001, citation > 12,600)

$$\min_{u \in BV(\Omega)} \left\{ TV(u) + \frac{\mu}{2} \int_\Omega (f-u)^2 dx \right\},$$

$TV(u)$: total variation of u

$$\min_{\Omega_i; m_i} \Big\{ \mathrm{Per}(\Omega_1; \Omega) + \lambda \sum_{i=0}^{1} \int_{\Omega_i} (m_i - f)^2 \, dx \Big\},$$

$$\Omega := \Omega_0 + \Omega_1$$

$\mathrm{Per}(\Omega_1; \Omega)$: perimeter of set Ω_1

Theorem

(Relation between ROF and Chan-Vese model) *Let $u^* \in BV(\Omega)$ solve the ROF model. For given $0 < m_0 < m_1 \leq 1$, let $\tilde{\Sigma} := \{x \in \Omega : u^*(x) > \frac{m_1+m_0}{2}\}$ fulfill $0 < |\tilde{\Sigma}| < |\Omega|$. Then $\tilde{\Sigma}$ is a minimizer of the Chan-Vese model for $\lambda := \frac{\mu}{2(m_1-m_0)}$ and fixed m_0, m_1. In particular, $(\tilde{\Sigma}, m_0, m_1)$ is a partial minimizer of the Chan-Vese model if $m_0 = \mathrm{mean}_f(\Omega \backslash \tilde{\Sigma})$ and $m_1 = \mathrm{mean}_f(\tilde{\Sigma})$.*

JSC, '17
X. Cai, et al.

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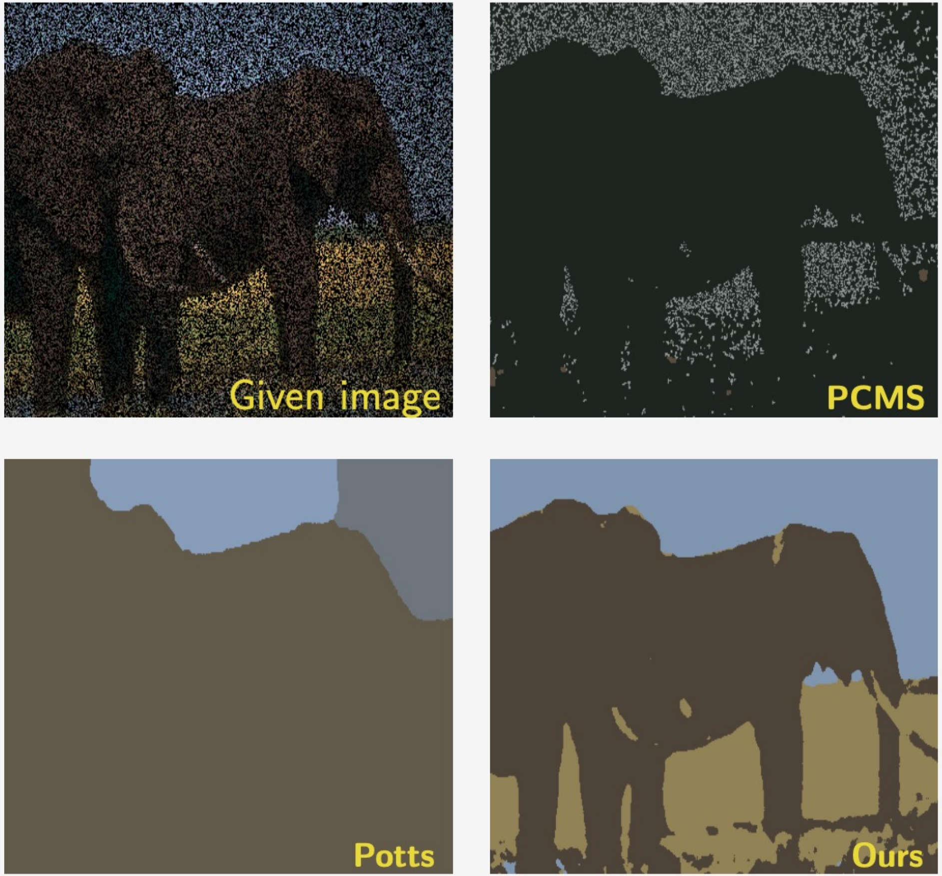
Colour image

Research Grants Council of Hong Kong
香港 研究資助局

Method: SLaT



IMA, '15
X. Cai, J. Fitschen,
M. Nikolova,
G. Steidl, M. Storath

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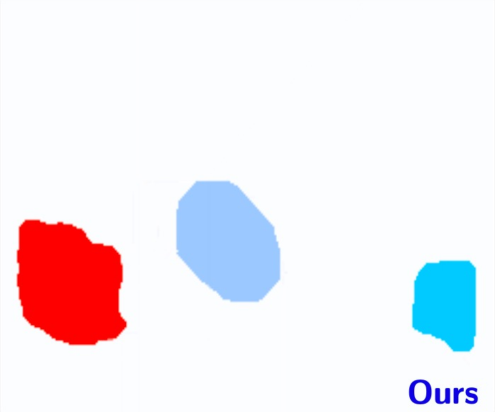
Disparity and optical flow

Algorithm for NP-hard problem $\|\nabla \cdot\|_0$



Computer vision

IEEE Tr., '15, '16, '19
J. Lee, X. Cai, D. Coomes
C.-B. Schönlieb, et al.

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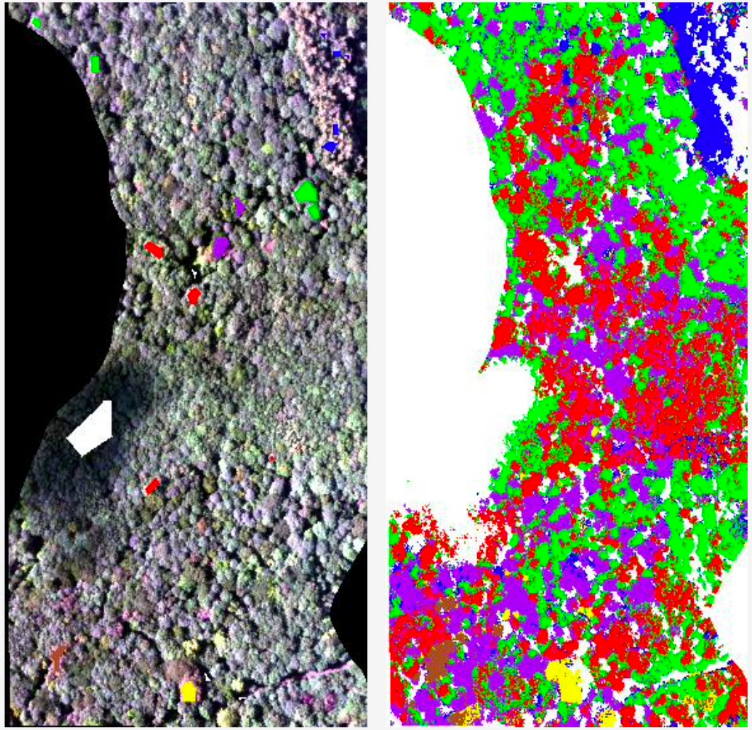
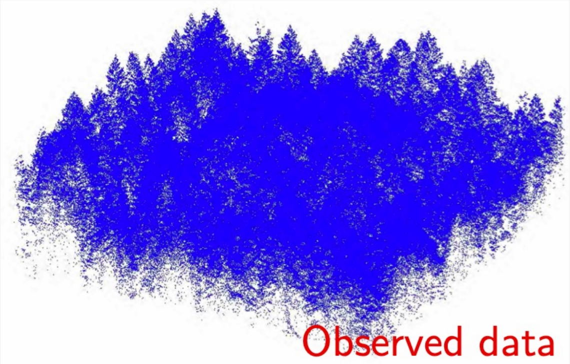
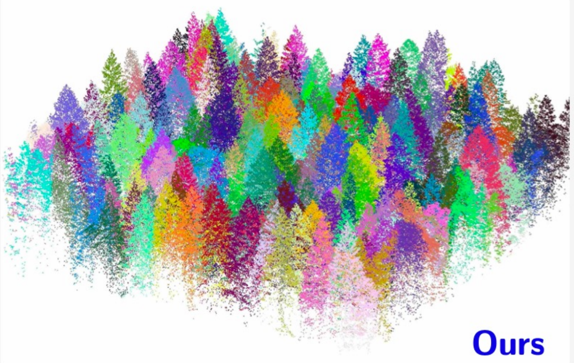
Hyperspectral



LiDAR





PR, '19
X. Cai, et al.

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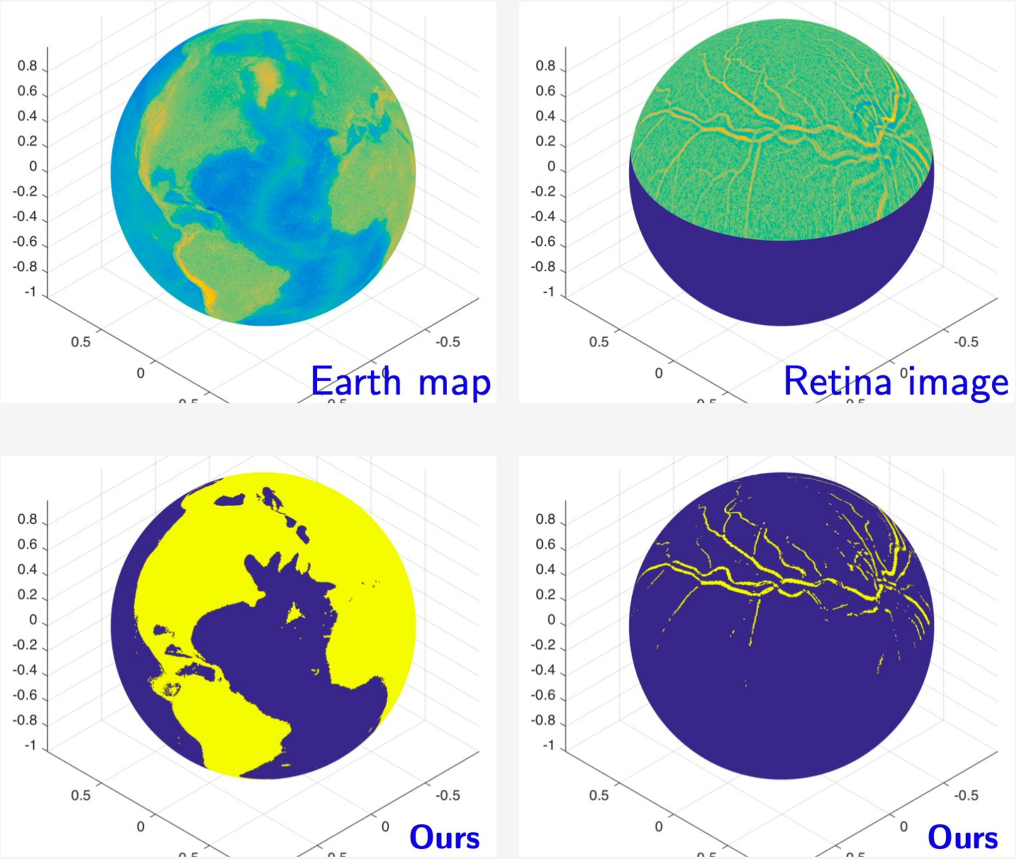
Spherical image

Wavelet-based algorithm

First segmentation paper on the sphere



3D image – tubular

SIIMS, '13
SSVM, '12
X. Cai, et al.

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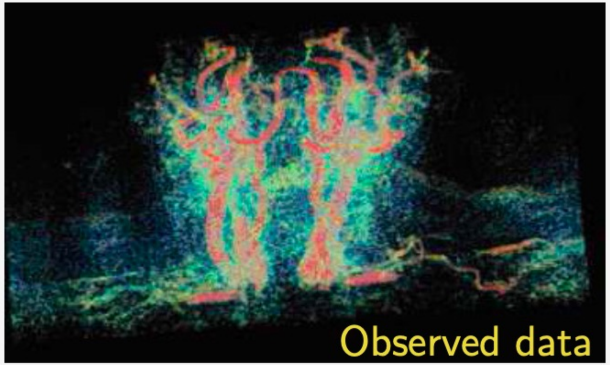
Wavelet-based algorithm



Data provided:
Prof. S. Morigi
Prof. F. Sgallari
Uni. of Bologna
Italy

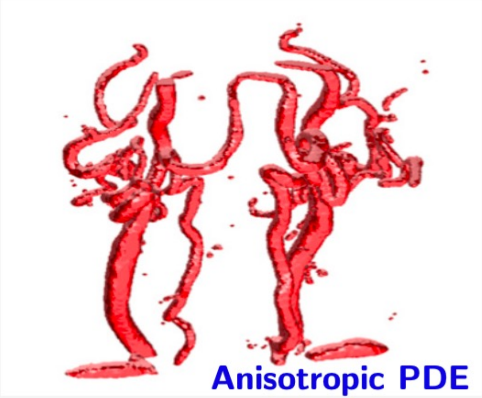


Image-guided radiotherapy

CIJ, '17
EUSIPCO, '21

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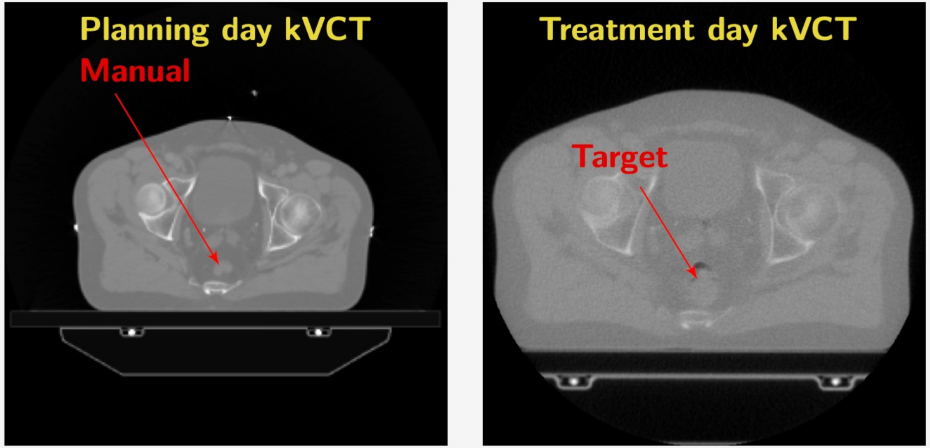

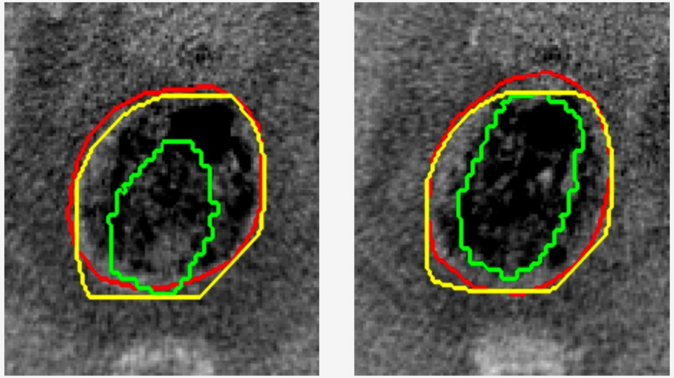

Manual
ours
Initial.

http://www.componc
org/research/voxtox

Recent: models leveraging deep learning

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Models proposed in our work, e.g.:

- $\min_x \left\{ \frac{\lambda}{2}\|y - \mathcal{A}x\|_2^2 + \|\mathcal{W}x\|_1 \right\}$
- $\min_g \left\{ \frac{\lambda}{2}\|f - \mathcal{A}g\|_2^2 + \frac{\mu}{2}\|\nabla g\|_2^2 + \|\nabla g\|_1 \right\}$
- $\mu\Phi(f, \mathcal{A}g) + \lambda\Psi(g, u_i, c_i) + \sum_{i=1}^{K} \int_\Omega |\nabla u_i|$
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- $\min_{u\in S} \left\{ \frac{1}{2}\|f - \mathcal{B}u\|_2^2 + \lambda\|\nabla u\|_0 \right\}$
- $\min_\psi \left\{ D[T(\psi), R] + \alpha\|\Delta\psi\|_2^2 \right\}$

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- ADMM
- Primal-dual
- Split-Bregman
- Augmented Lagrangian

Sparse regularizations

- $\|\cdot\|_0$, $\|\cdot\|_1$, $\|\cdot\|_2$
- with $\nabla, \Delta, \mathcal{W}$
- $\mathcal{W}$: Wavelet transform

Conclusions

1. Computer vision works and has a great future
2. Big difference between data-driven and model-driven
3. Gap is becoming smaller
4. What will happen in the future?

We have more to learn …