Microscopy, in a Heartbeat

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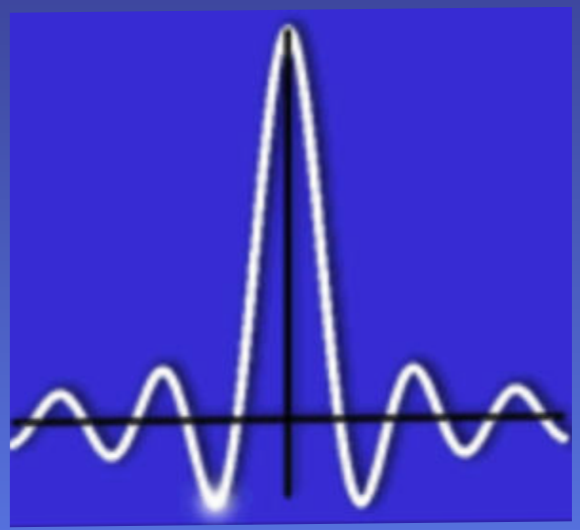
Twenty Years of Biomedical Imaging and Splines

23 March 2018, EPFL, Lausanne

My journey @EPFL towards splines (1)

My first signal processing student project (1999)



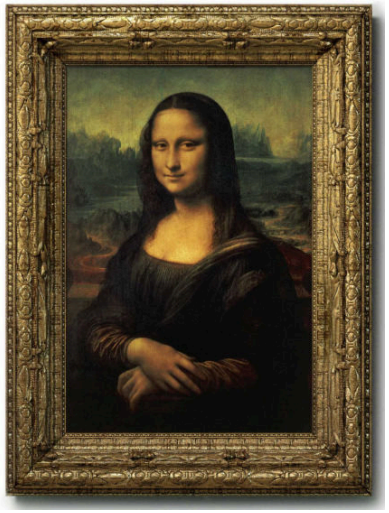
My journey @EPFL towards splines (2)

My second student project in signal processing (diplôme 2000)

How BIG affected my hobbies...

Before BIG

Playing with cool Danish building blocks



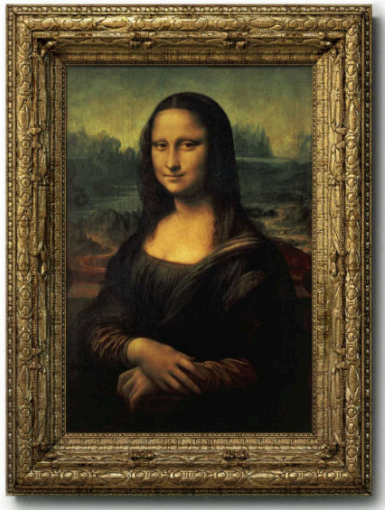
Enjoying Fine Art

Taking pictures of rare wildflowers

... and how life became 100% splines

Before BIG

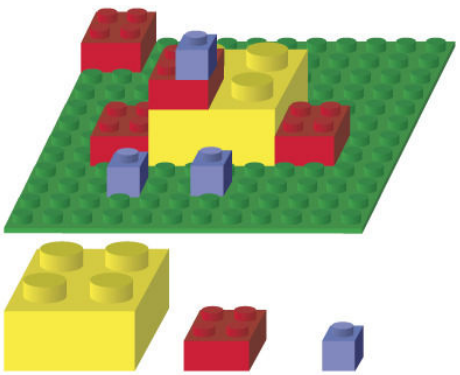
Playing with cool Danish building blocks



Enjoying Fine Art

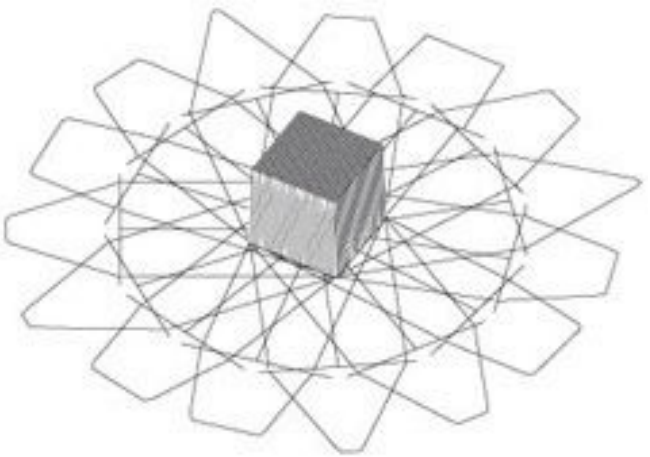
Taking pictures of rare wildflowers

While at BIG



Playing with cool Danish building blocks

Enjoying Fine Art

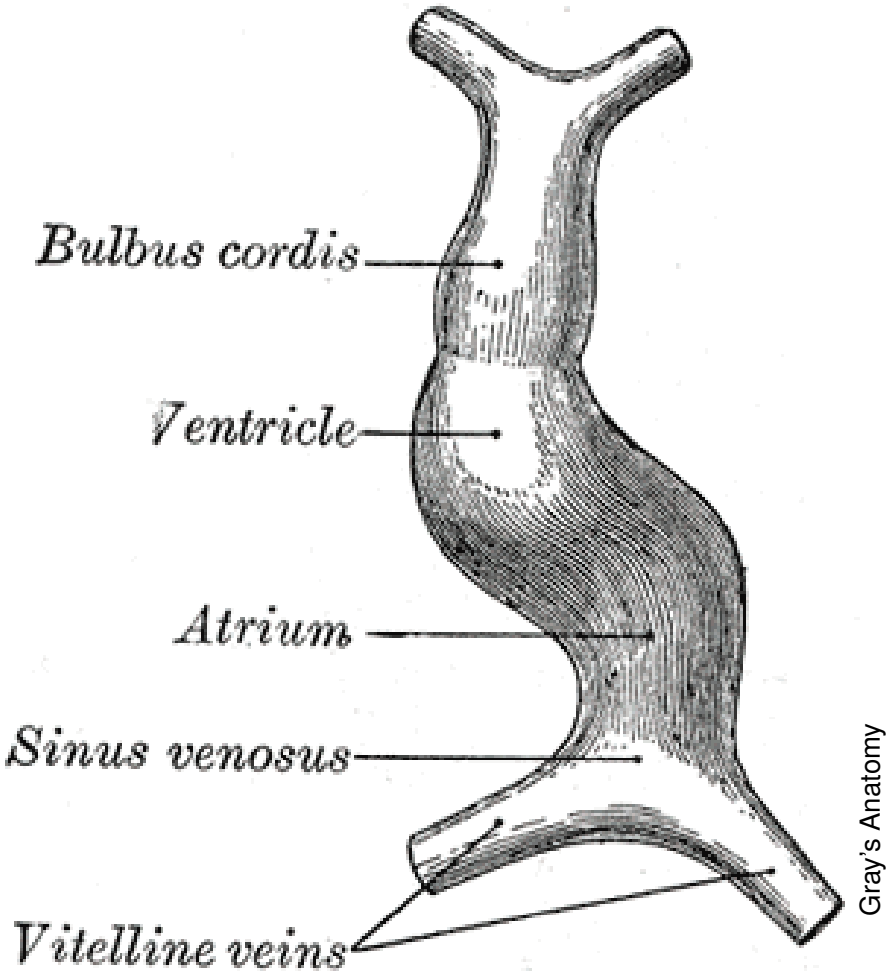


Taking pictures of rare wildflowers

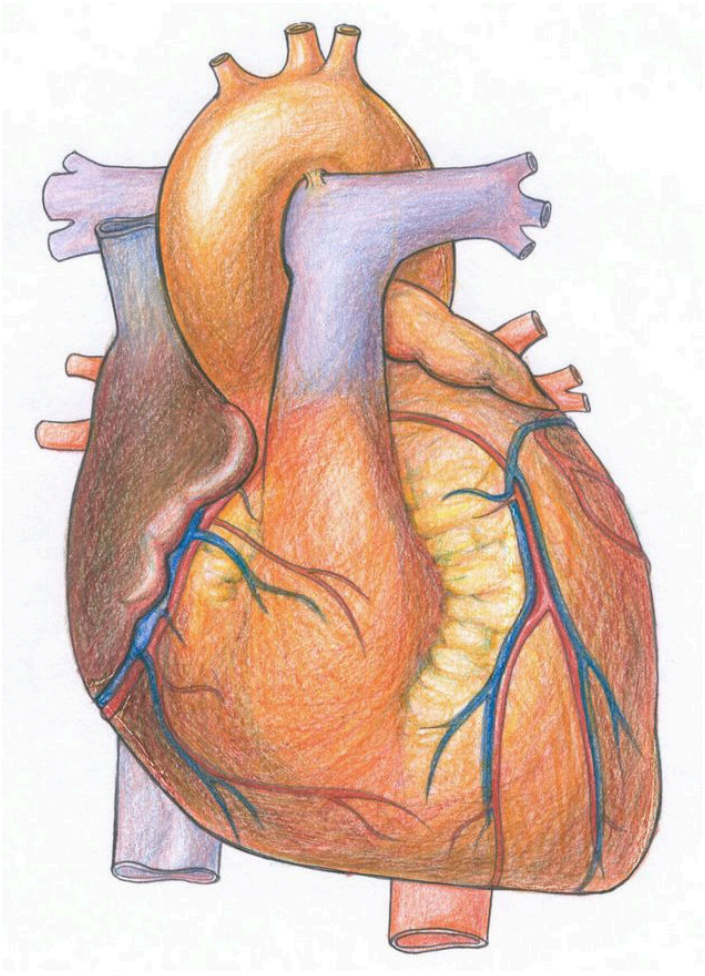
To get hired as a PhD student @ BIG, is wearing a tie required?

Hint: even if it is not necessary, you can always recycle the tie to illustrate sampling in your image processing class.

Lifer after BIG: image processing to study heart development



Gray's Anatomy



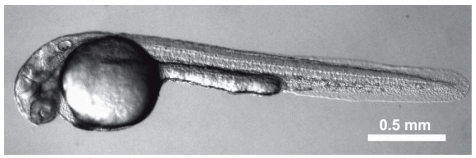
Day 22 (Human) **Adult (Human)**

Why it matters:

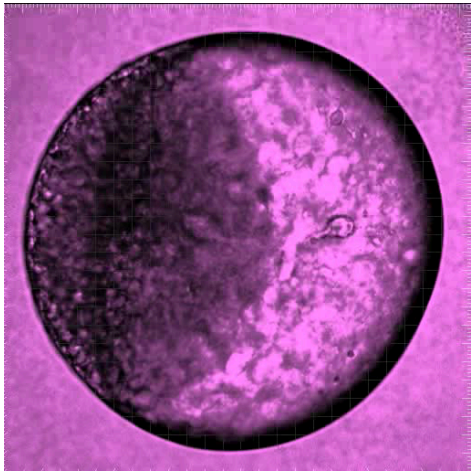
Congenital heart defects occur in 0.8% of newborn infants and are the leading cause of birth defect-related deaths

Imaging the developing heart: challenging requirements…

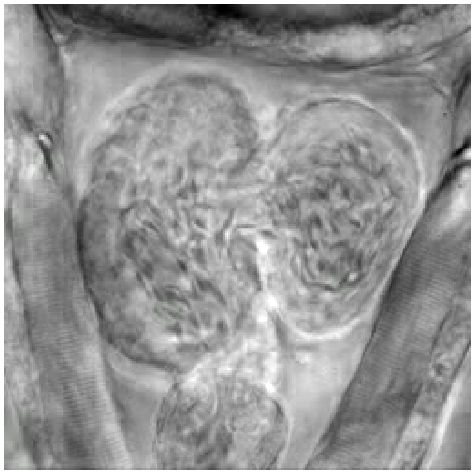
It's small:
heart is a few hundred μm, cells few μm;
$\Rightarrow$ requires magnification



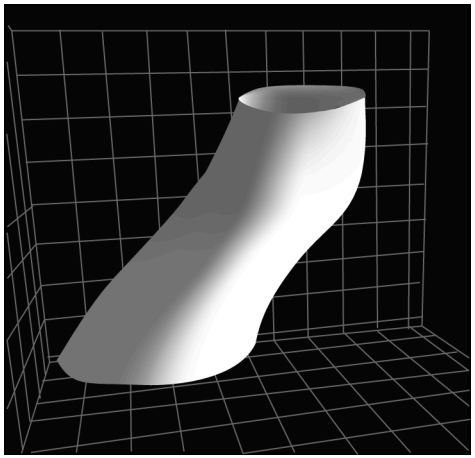
It's slow:
Development over hours, days



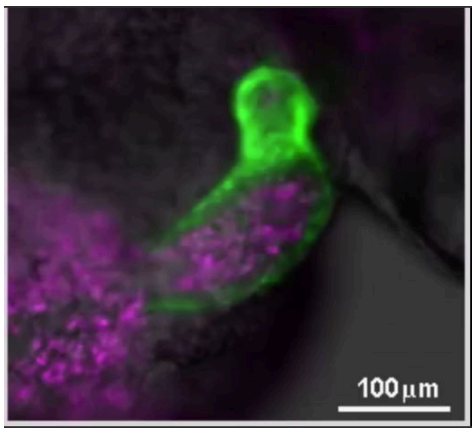
It's fast:
2-3 Heart beats per second



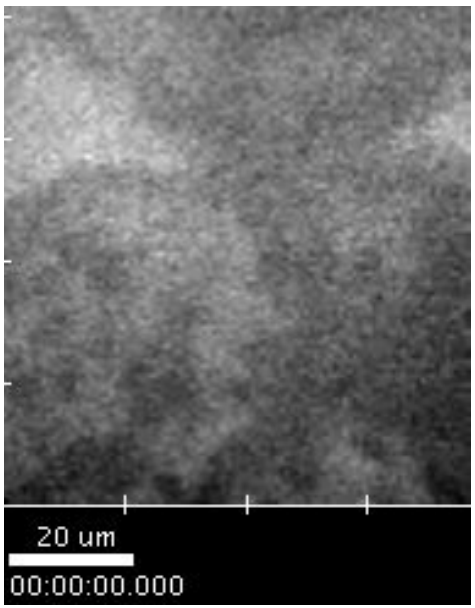
It's 3D (when most microscopes are fast only in 2D)



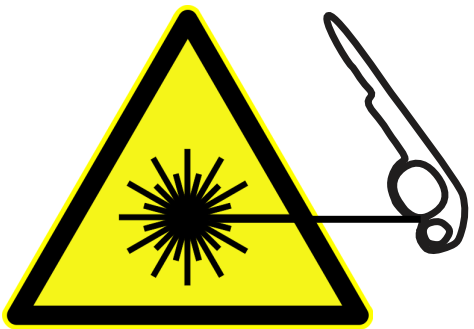
One channel is rarely enough



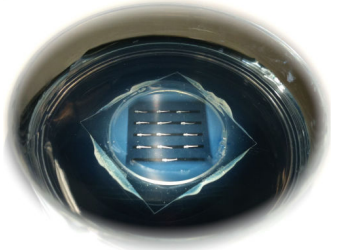
Signal is weak

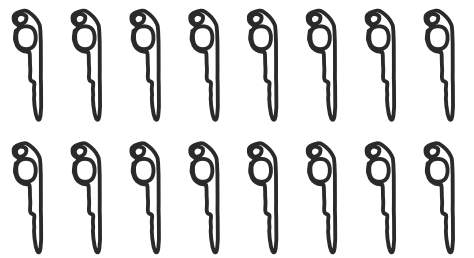


Sample is fragile

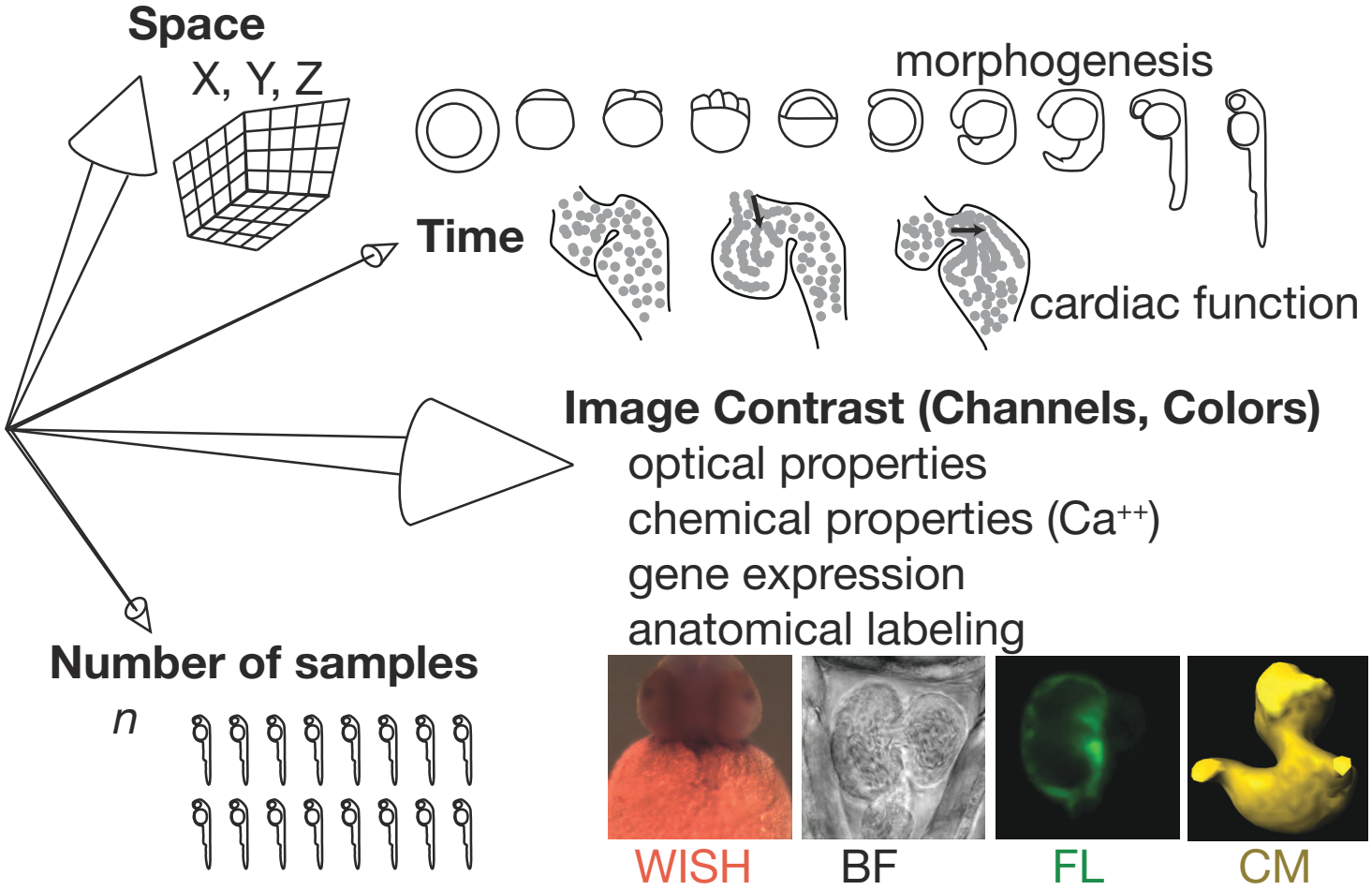


No statistics with n = 1





. . . dimensions are too many for naïve imaging

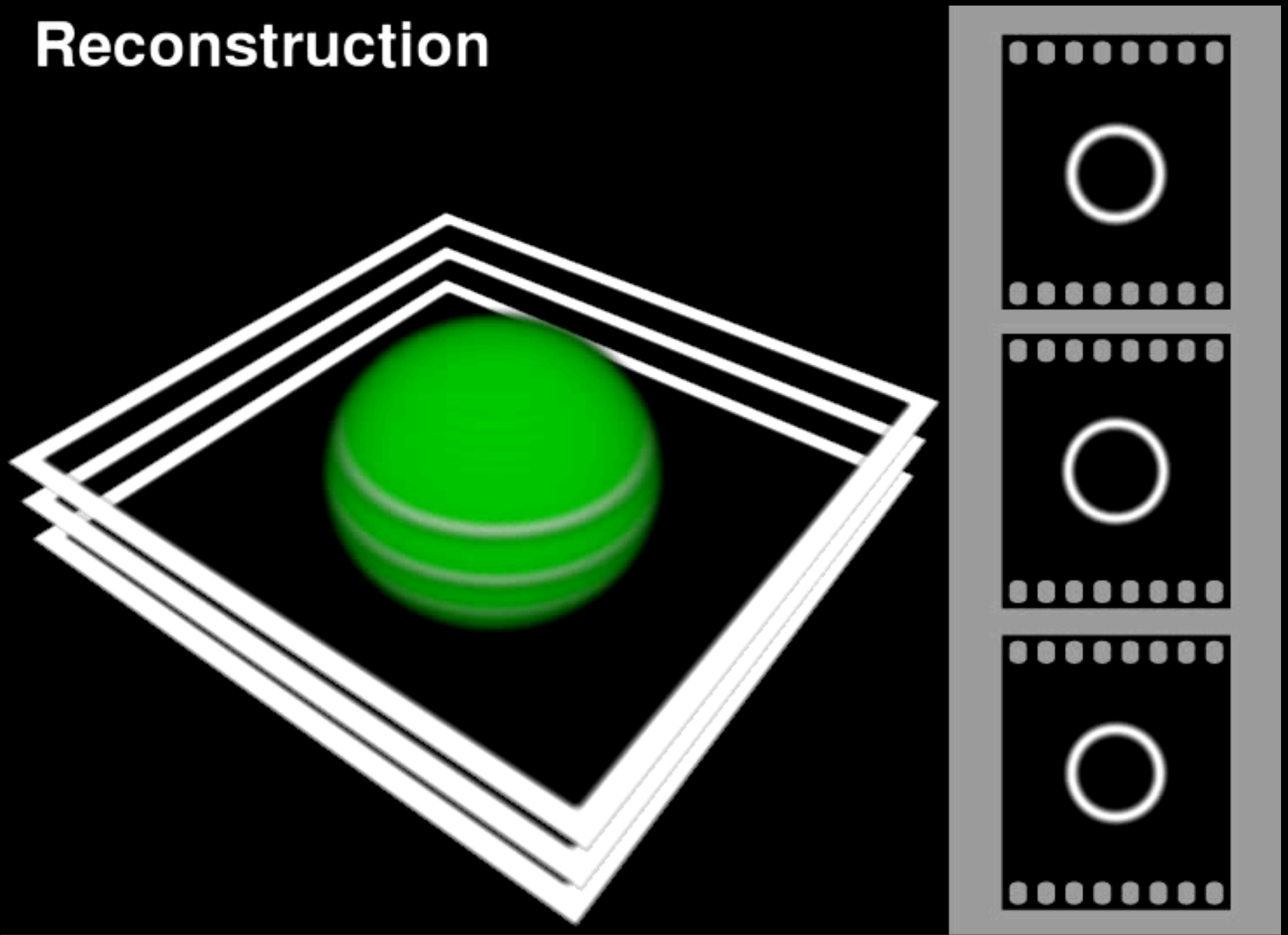


Bottlenecks that limit resolution and breadth

- optical resolving power, data bandwidth
- available time
- sample integrity

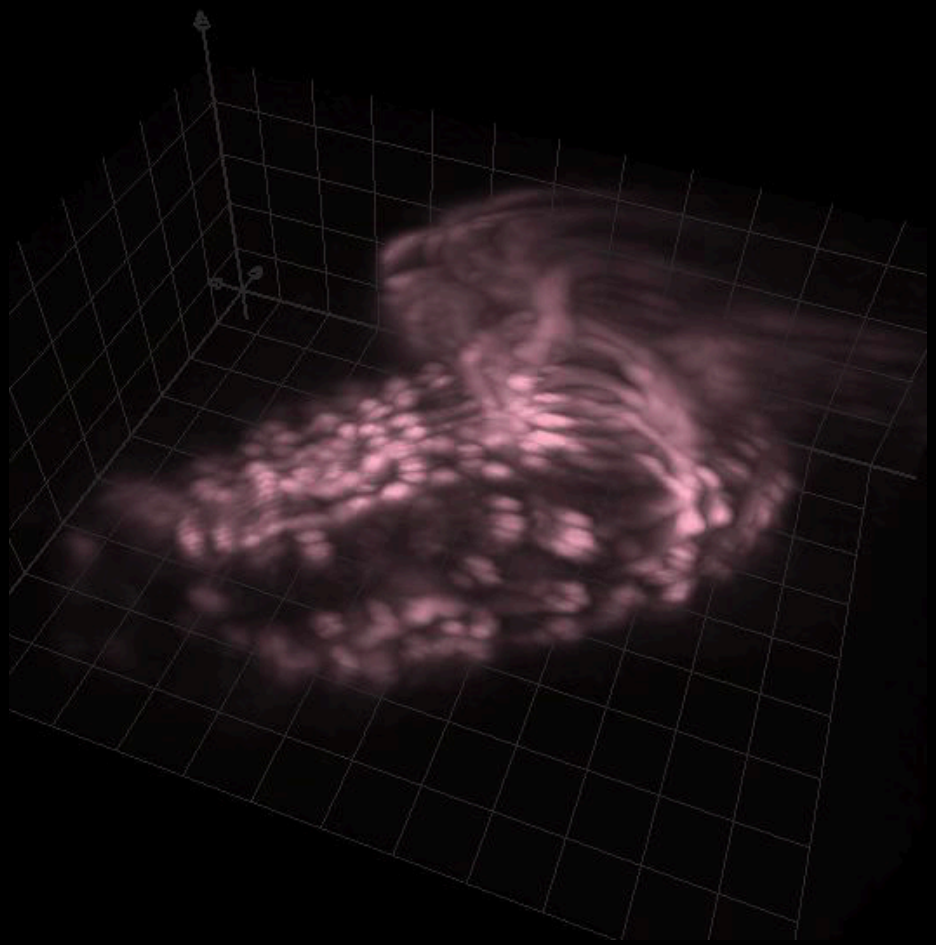
Can we perform high-dimensional imaging without sacrificing resolution or image quality?

The trick: sample space sequentially over multiple heartbeats

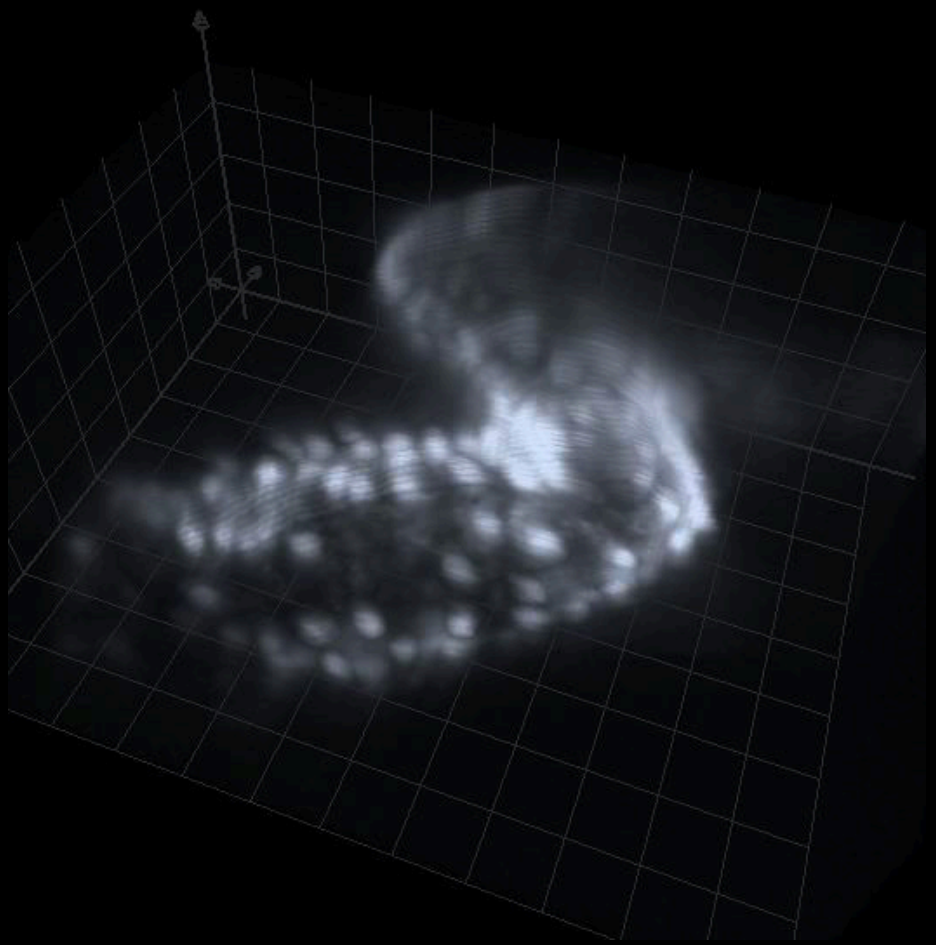


4D, in vivo, and fast microscopy becomes possible

Before synchronization



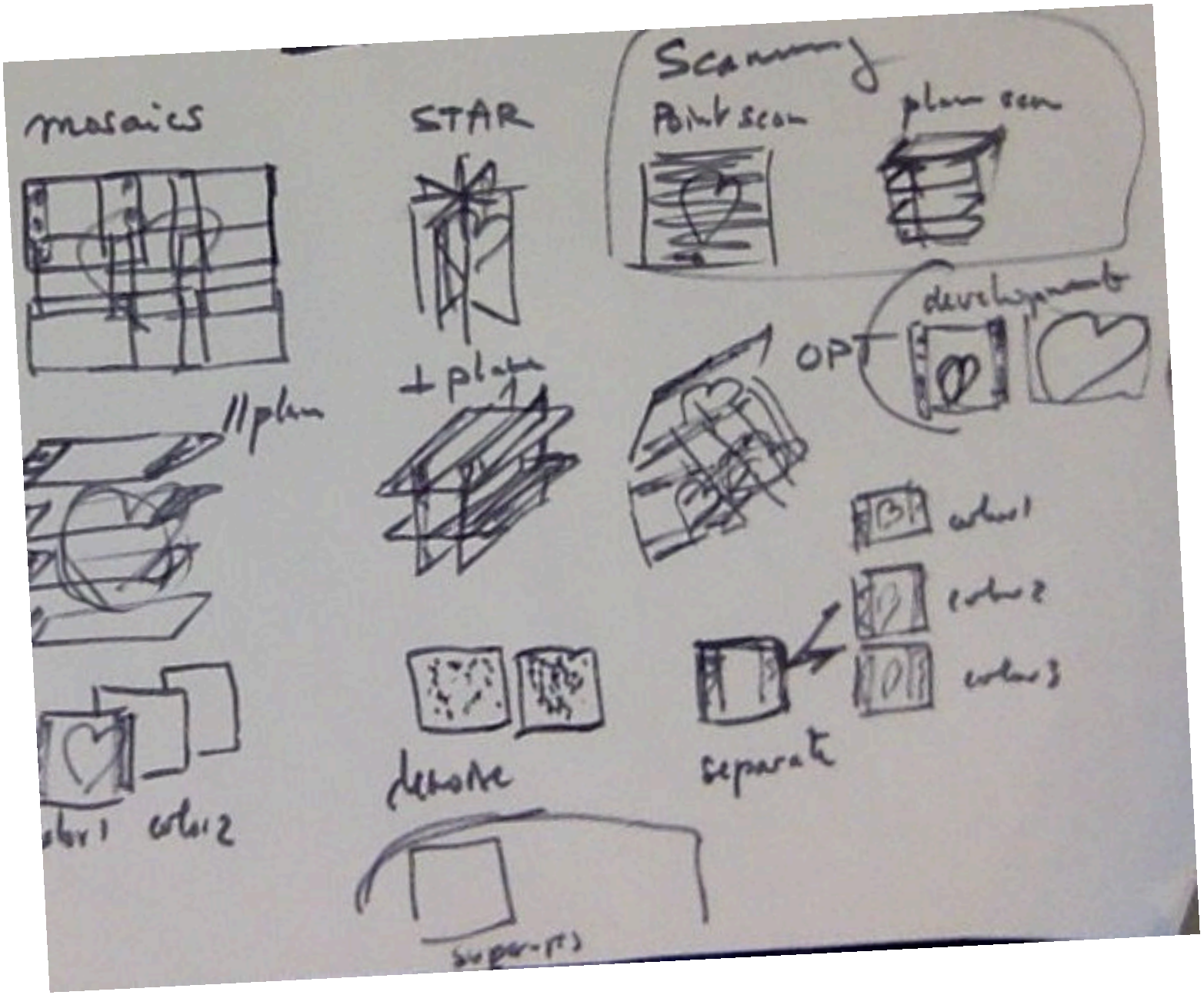
After synchronization



A.S. Forouhar, ***ML***

[Tg(*cmlc2*:GFP) 38 hpf zebrafish, *Huai-Jen Tsai, National Taiwan University*]

Many variations on the same theme over the years...



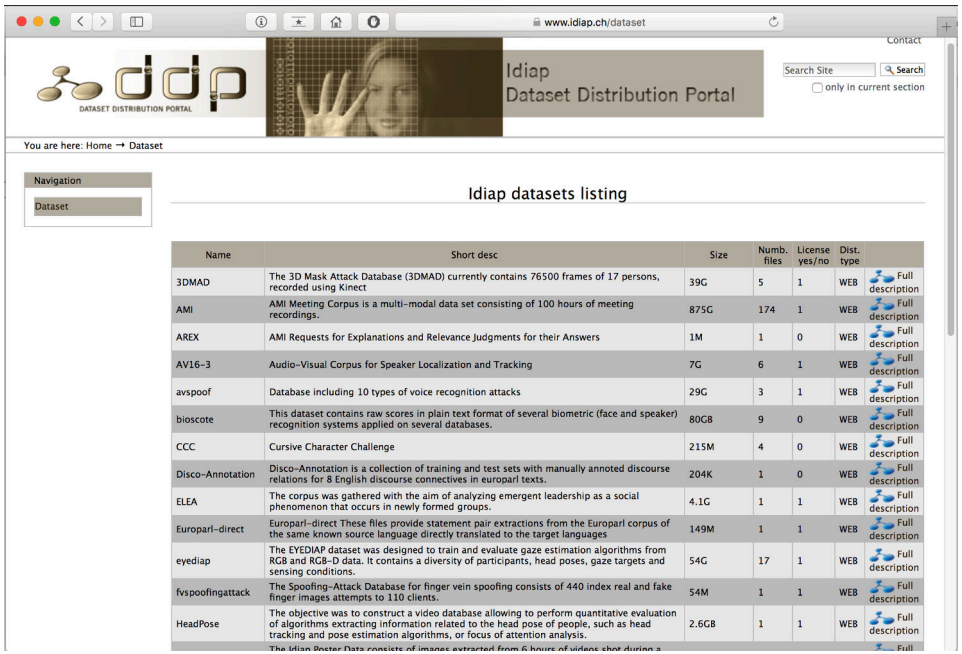
. . . still many configurations that remain to be cracked!

Reproducible research: different ways to share (or not to share) data

Distribute the data:

Over 30 databases are distributed by Idiap:

`www.idiap.ch/dataset`

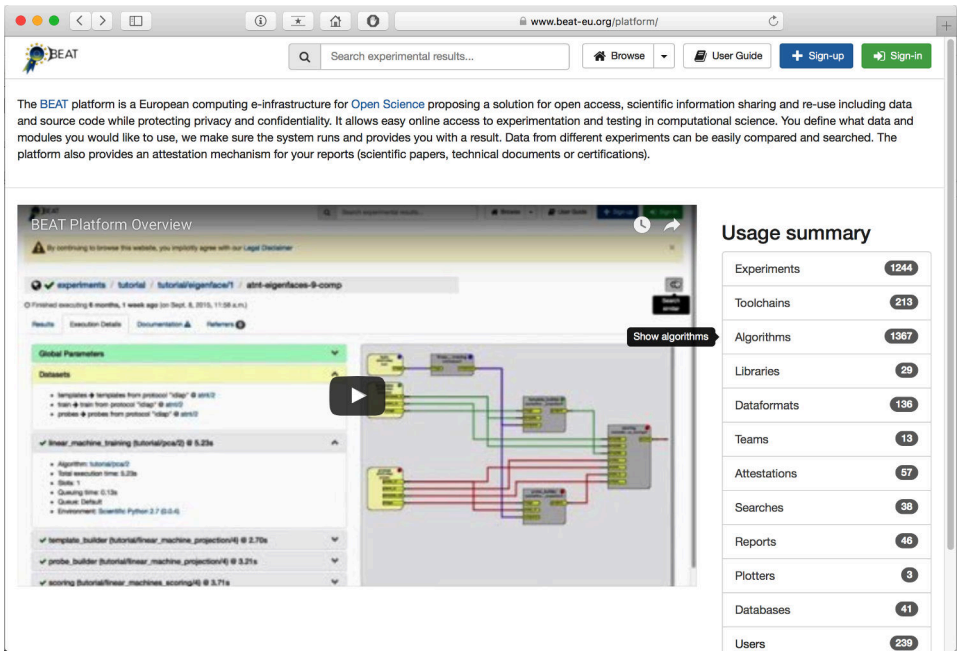


Name	Short desc	Size	Numb. files	License yes/no	Dist. type	
3DMAD	The 3D Mask Attack Database (3DMAD) currently contains 76500 frames of 17 persons, recorded using Kinect	39G	5	1	WEB	Full description
AMI	AMI Meeting Corpus is a multi-modal data set consisting of 100 hours of meeting recordings.	875G	174	1	WEB	Full description
AREX	AMI Requests for Explanations and Relevance Judgments for their Answers	1M	1	0	WEB	Full description
AV16-3	Audio-Visual Corpus for Speaker Localization and Tracking	7G	6	1	WEB	Full description
avspoof	Database including 10 types of voice recognition attacks	29G	3	1	WEB	Full description
bioscote	This dataset contains raw scores in plain text format of several biometric (face and speaker) recognition systems applied on several databases.	80GB	9	0	WEB	Full description
CCC	Cursive Character Challenge	215M	4	0	WEB	Full description
Disco-Annotation	Disco-Annotation is a collection of training and test sets with manually annoted discourse relations for 8 English discourse connectives in europarl texts.	204K	1	0	WEB	Full description
ELEA	The corpus was gathered with the aim of analyzing emergent leadership as a social phenomenon that occurs in newly formed groups.	4.1G	1	1	WEB	Full description
Europarl-direct	Europarl-direct These files provide statement pair extractions from the Europarl corpus of the same known source language directly translated to the target languages	149M	1	1	WEB	Full description
eyediap	The EYEDIAP dataset was designed to train and evaluate gaze estimation algorithms from RGB and RGB-D data. It contains a diversity of participants, head poses, gaze targets and sensing conditions.	54G	17	1	WEB	Full description
fvspoofingattack	The Spoofing-Attack Database for finger vein spoofing consists of 440 index real and fake finger images attempts to 110 clients.	54M	1	1	WEB	Full description
HeadPose	The objective was to construct a video database allowing to perform quantitative evaluation of algorithms extracting information related to the head pose of people, such as head tracking and pose estimation algorithms, or focus of attention analysis.	2.6GB	1	1	WEB	Full description

Sequester the data:

BEAT platform (evaluation of biometry algorithms on sequestered data)

S. Marcel *et al.*



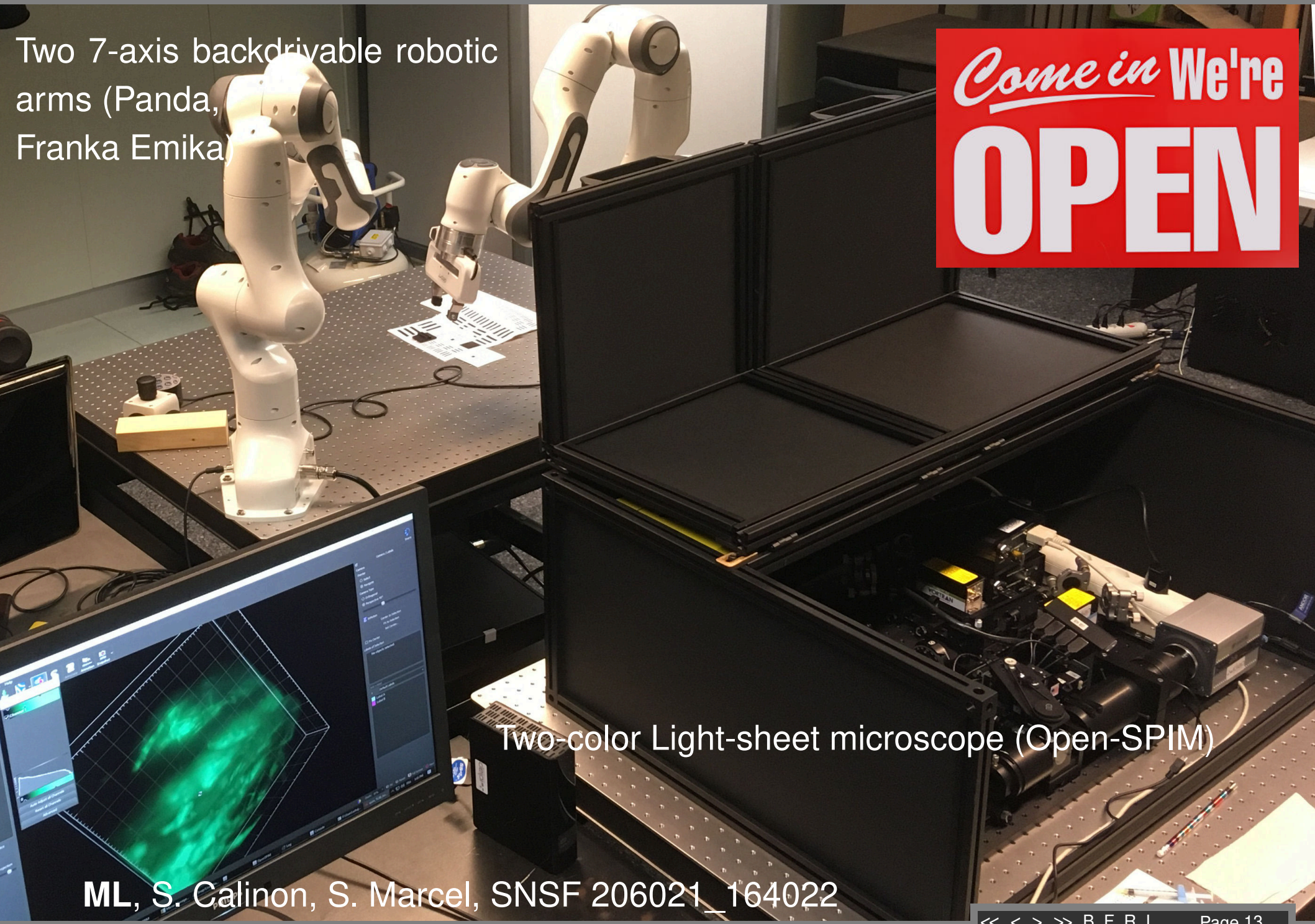
Still a need:

dynamic image data sets for computational imaging problems are nice to have but there are too few available

Proposal (2015):

Set up an image acquisition platform to collect and share dynamic images over a broad range of scales and applications

2018: A platform in support of dynamic computational imaging

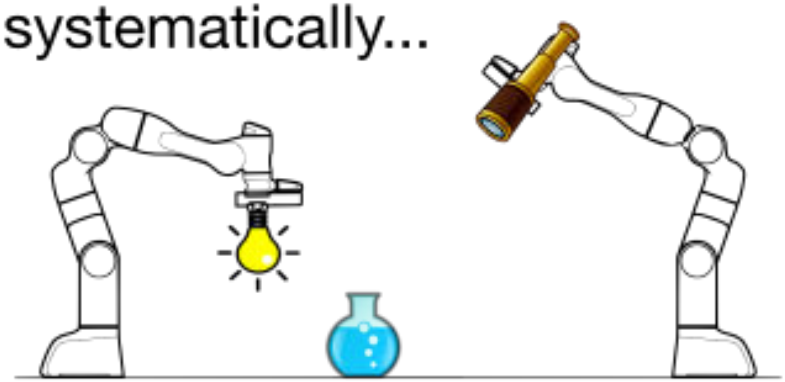


ML, S. Calinon, S. Marcel, SNSF 206021_164022

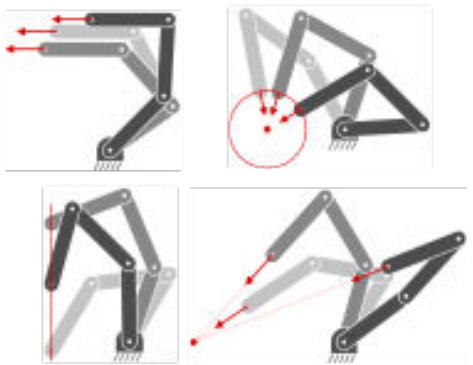
Imaging Motion: Explore, Constrain, Reproduce

One Platform to ...

... explore motion space systematically...



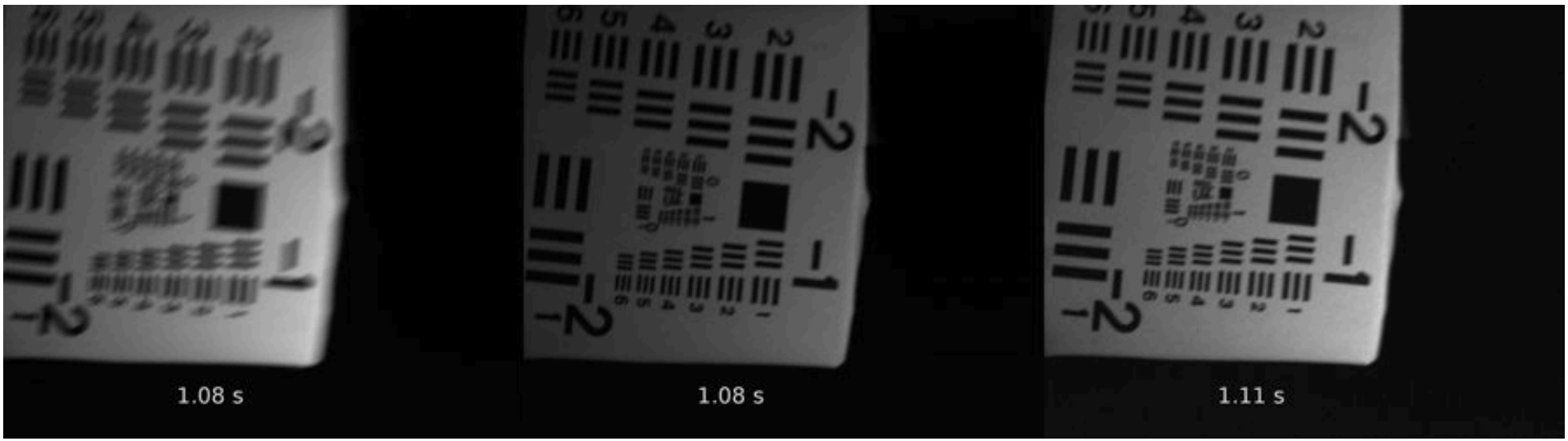
... constrain motion or view...



... and reproduce arbitrary motion:

Example: *Comparing performance of acquisition and/or reconstruction methods*

Long exposure | Strobed exposure | Temporal super-resolution



Christian Jaques, Adrian Shajkofci, Emmanuel Pignat, S. Calinon, ***MI***

Summary

- Imaging the developing heart
  - Imaging is a key component but constraints are challenging
  - Proposed solution: sequential sampling of the data space (over multiple heart beats) with post-processing
  - Many variations, still many open problems
- Computational imaging
  - Need more quality data to work with
  - Developed an imaging platform at Idiap
  - Platform is open for collaborators!

Acknowledgments

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UCSB
Nikhil Chacko (PhD'15)
Kevin Chan (PhD'17)
Michael Lee (PhD'15)
Sandeep Bhat (PhD'13)
Jungho Ohn (PhD'13)
Idiap
Christian Jaques
Olivia Mariani
Adrian Shajkofci
Caltech
Arian S. Forouhar
Julien Vermot (@IGBMC)
Le Trinh(@USC)
Mory Gharib
Scott E. Fraser (@USC)
BCM Houston (Mouse)
Irina Larina
Mary E. Dickinson
U. Houston (OCT)
Kirill Larin
a*star, Singapore
(Heart transgenics)
Kar Lai Poon, Vlad Korzh
Hard- and Software
Imaris (Bitplane AG)
μManager (Nico Stuurman)
Leica Microsystems
Olympus
Carl Zeiss, AIM
Zebrafish
Shuo Lin, UCLA
H.-J. Tsai, Nat. Taiwan U.
Le Trinh, USC
ZIRC
Funding
Swiss National Science Foundation
NIH (NHLBI R01 HL078694)
NSF (DMR 0960331)
Hellman Family Fellowship
Santa Barbara Cottage Hospital
Regent's Junior Faculty Fellowship

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