# K-Wire Tracking in 3D Camera Views

Seminar by Athira Jacob

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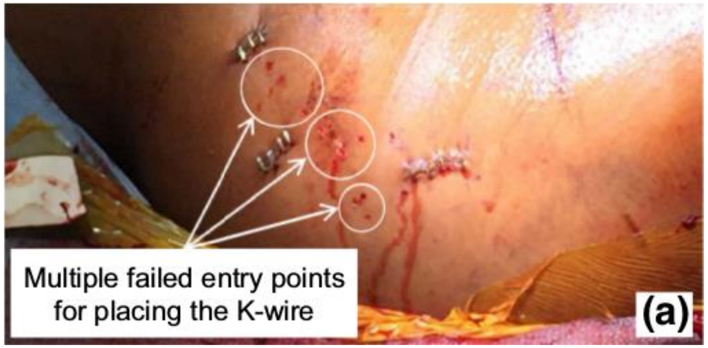
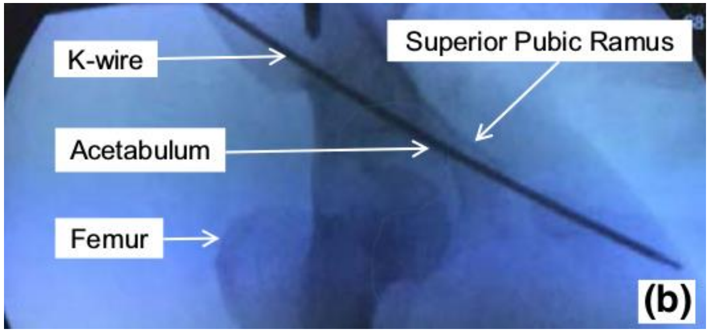
# Recap: Background

- K-wire insertion currently requires many X-rays
- Misplacement could damage important structures in the body
- Current tracking solutions are ineffective for K-wire
  - Traditional computer vision solutions fail
  - Trackers cannot be placed on it
- Propose to use convolutional neural network trained on RGB images




Multiple entry wounds

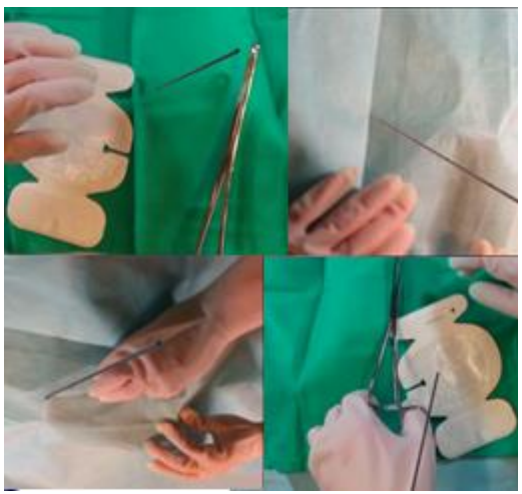


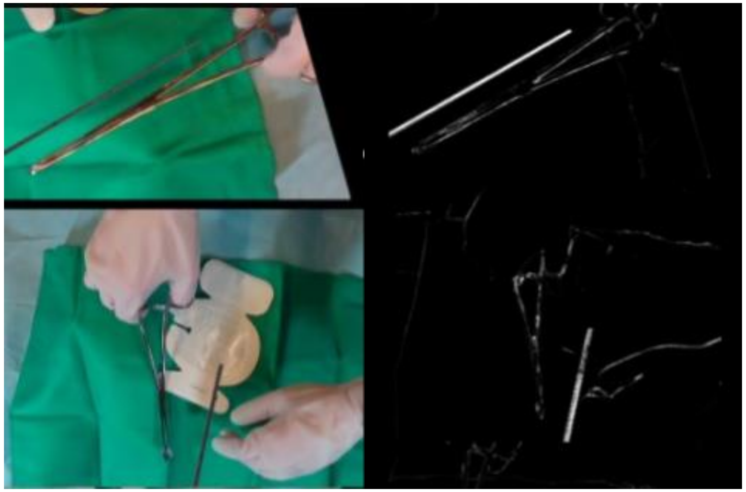

X-ray image of hip region in pelvic surgery

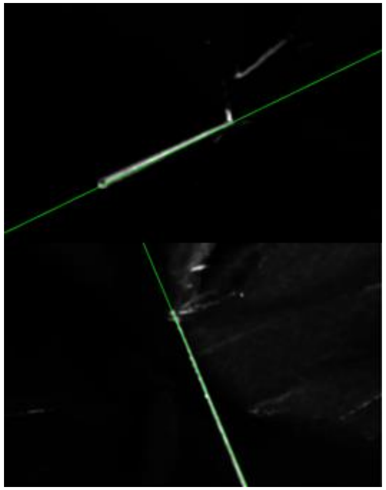
Images from Fischer, Marius, et al. "Preclinical usability study of multiple augmented reality concepts for K-wire placement." International Journal of Computer Assisted Radiology and Surgery 11.6 (2016): 1007-1014.

# Recap: Workflow

Create data → 2D segmentation of K-wire using CNN's → Estimate orientation/pose







# I. Pre-clinical usability study (CAMP, JHU; I JCARS 2016)

Int J CARS (2016) 11:1007–1014
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ORIGINAL ARTICLE

## Preclinical usability study of multiple augmented reality concepts for K-wire placement

Marius Fischer[1,2] · Bernhard Fuerst[2,3] · Sing Chun Lee[2] · Javad Fotouhi[2] · Severine Habert[3] · Simon Weidert[1] · Ekkehard Euler[1] · Greg Osgood[4] · Nassir Navab[2,3]

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**Abstract**
*Purpose* In many orthopedic surgeries, there is a demand

augmentation on 2D video, and 3D surface reconstruction augmented by digitally reconstructed radiographs and live

Fischer, Marius, et al. "Preclinical usability study of multiple augmented reality concepts for K-wire placement." *International Journal of Computer Assisted Radiology and Surgery* 11.6 (2016): 1007-1014.

# Introduction

- K-wire placement: widely prevalent and challenging minimally invasive technique

- Main challenge: Mental alignment of patient, medical instruments, and the intra-operative X-ray images

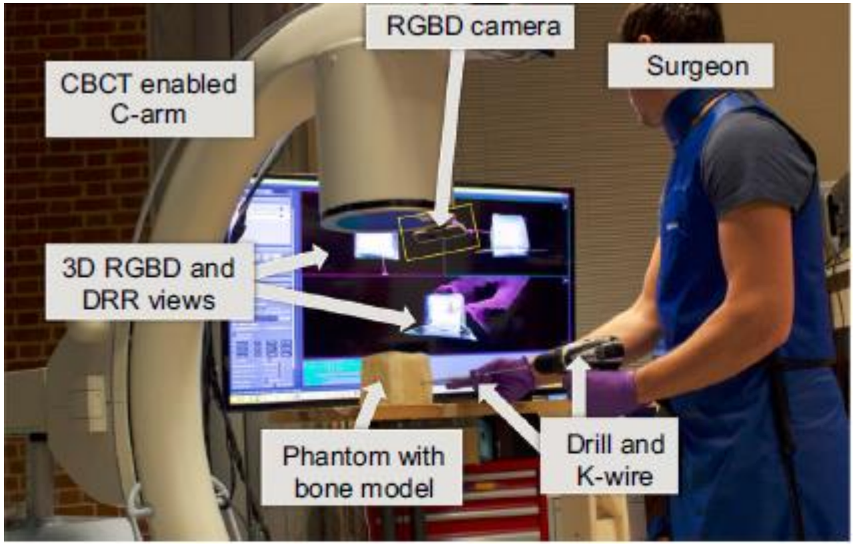
- K-wire insertion currently requires many X-rays
  - Misplacement could damage important structures in the body
  - Multiple entry wounds
  - High radiation exposure

# Method

**Experiments:**

- Phantom design:
  - Thin, tubular mesh made out of aluminium, enclosed in methylene bisphenyl diisocyanate (MDI) foam, which is stiff, lightweight, and not radiopaque
  - Begin and end of the bone were marked with a rubber radiopaque ring
  - Similar haptic feedback

- 7 surgeons, each performed three K-wire placements



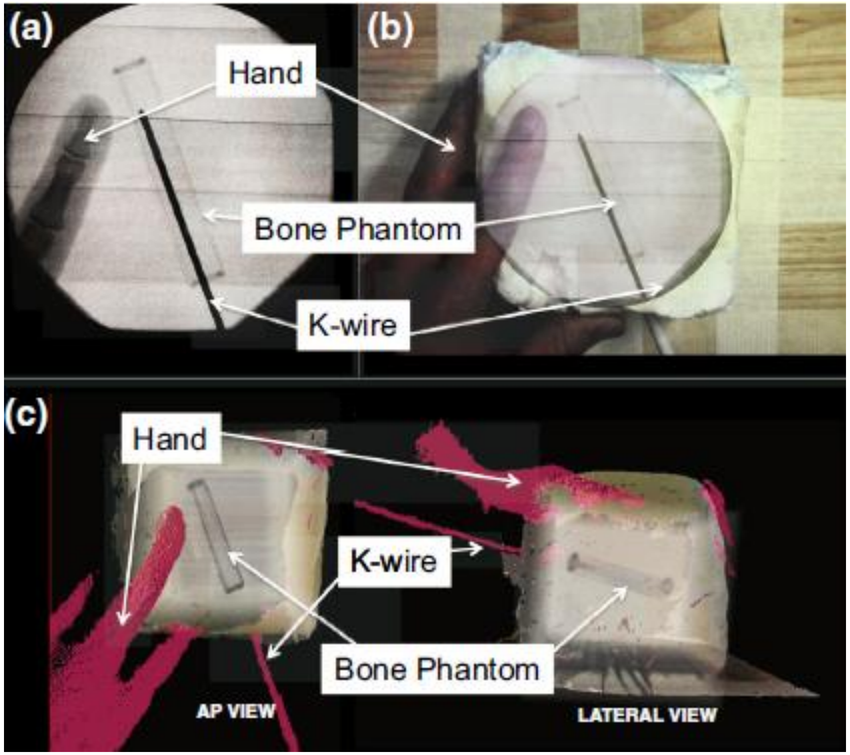
# Method

**Imaging systems compared:**

a) *Conventional intra-operative X-ray imaging*

b) *2D RGB video and X-ray visualization*

c) *3D RGBD and DRR via CBCT visualization*



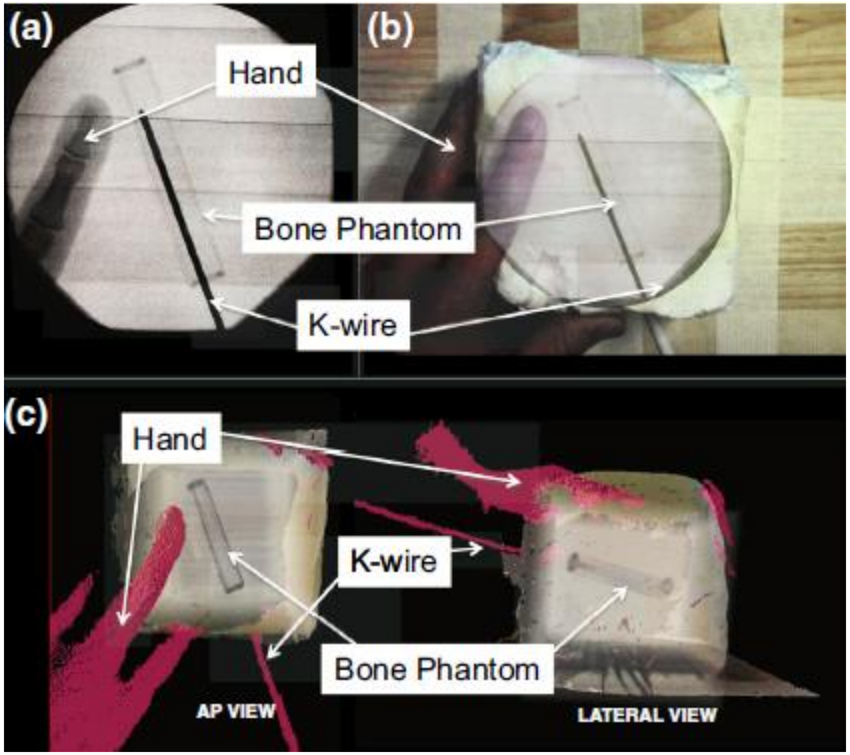
# Method

**Imaging systems compared:**

a) *Conventional intra-operative X-ray imaging*
- Baseline
- Operated in digital radiography mode

b) *2D RGB video and X-ray visualization*

c) *3D RGBD and DRR via CBCT visualization*



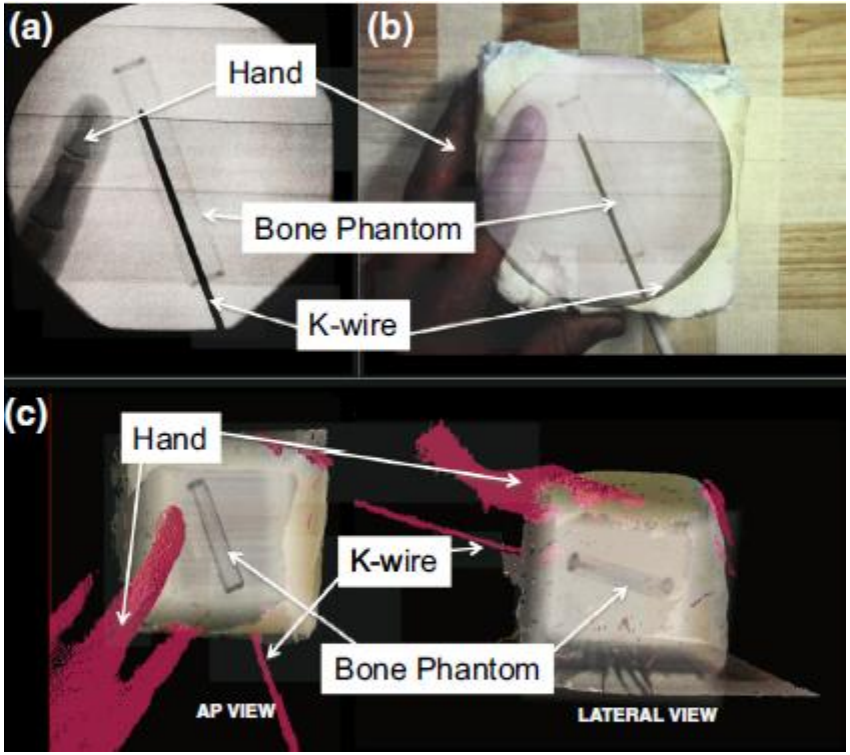
# Method

**Imaging systems compared:**

a) *Conventional intra-operative X-ray imaging*

b) *2D RGB video and X-ray visualization*
- X-ray augmented onto 2D camera view
- X-ray – camera calibration with a single plane phantom with radiopaque markers
- Requires repositioning of the C-arm to change the optical and X-ray view

c) *3D RGBD and DRR via CBCT visualization*



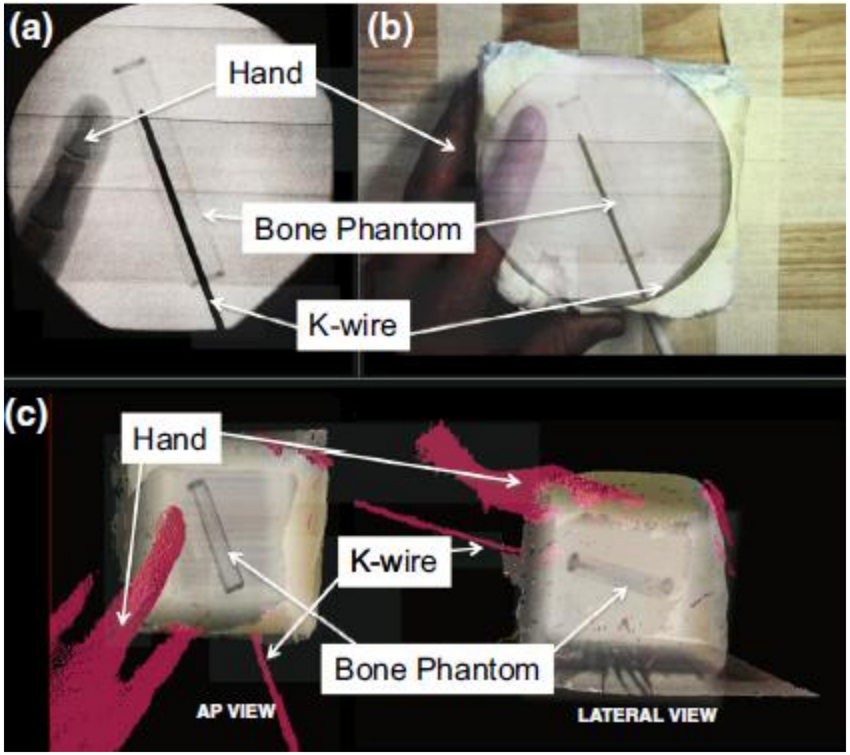
# Method

**Imaging systems compared:**

a) *Conventional intra-operative X-ray imaging*

b) *2D RGB video and X-ray visualization*

c) *3D RGBD and DRR via CBCT visualization*
- Augmentation of digitally reconstructed radiographs from cone beam CT onto patient surface from RGBD camera
- Allows simultaneous visualization from multiple, arbitrary views
- CBCT-RGBD calibration through surface matching

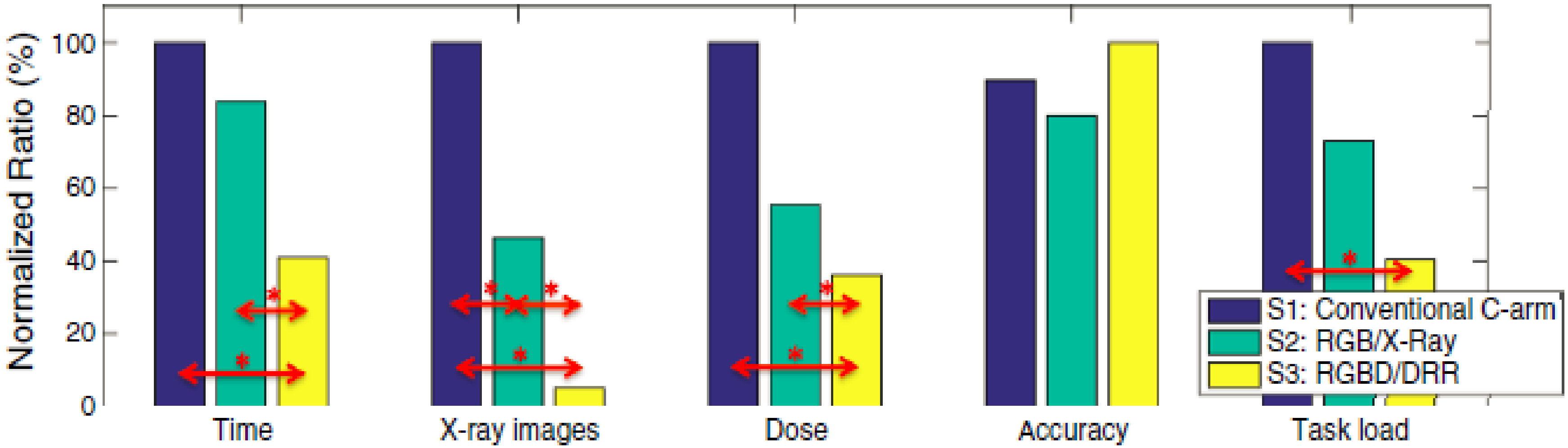


# Method

**Evaluation metrics:**

1. Duration of each K-wire placement
2. Number or X-ray images
3. Cumulative dose
4. Error in placement
   - Average distance  from the center line of bone phantom
5. Surgical task load
   - Surgical Task Load Index questionnaire (SURG-TLX)

# Results




- Rigorous statistical testing was performed to prove significance
- RGBD/ DRR gives significant improvements in all metrics except accuracy

# Conclusions

- 3D visualization yields the most benefit in terms of surgical duration, number of X-ray images taken, overall radiation dose, and surgical workload
- Movement of the C-arm or surgical table may lead to loss of tracking, which results in an outdated mixed reality visualization
- Mixed reality visualizations currently do not provide an augmentation of a tracked tool: this could give more pronounced improvements

# II. U-Net (University of Freiburg, MICCAI 2015)

## U-Net: Convolutional Networks for Biomedical Image Segmentation


Olaf Ronneberger, Philipp Fischer, and Thomas Brox

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**Abstract.** There is large consent that successful training of deep networks requires many thousand annotated training samples. In this paper, we present a network and training strategy that relies on the strong use of data augmentation to use the available annotated samples more efficiently. The architecture consists of a contracting path to capture context and a symmetric expanding path that enables precise localiza-



Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer International Publishing, 2015.

# Background

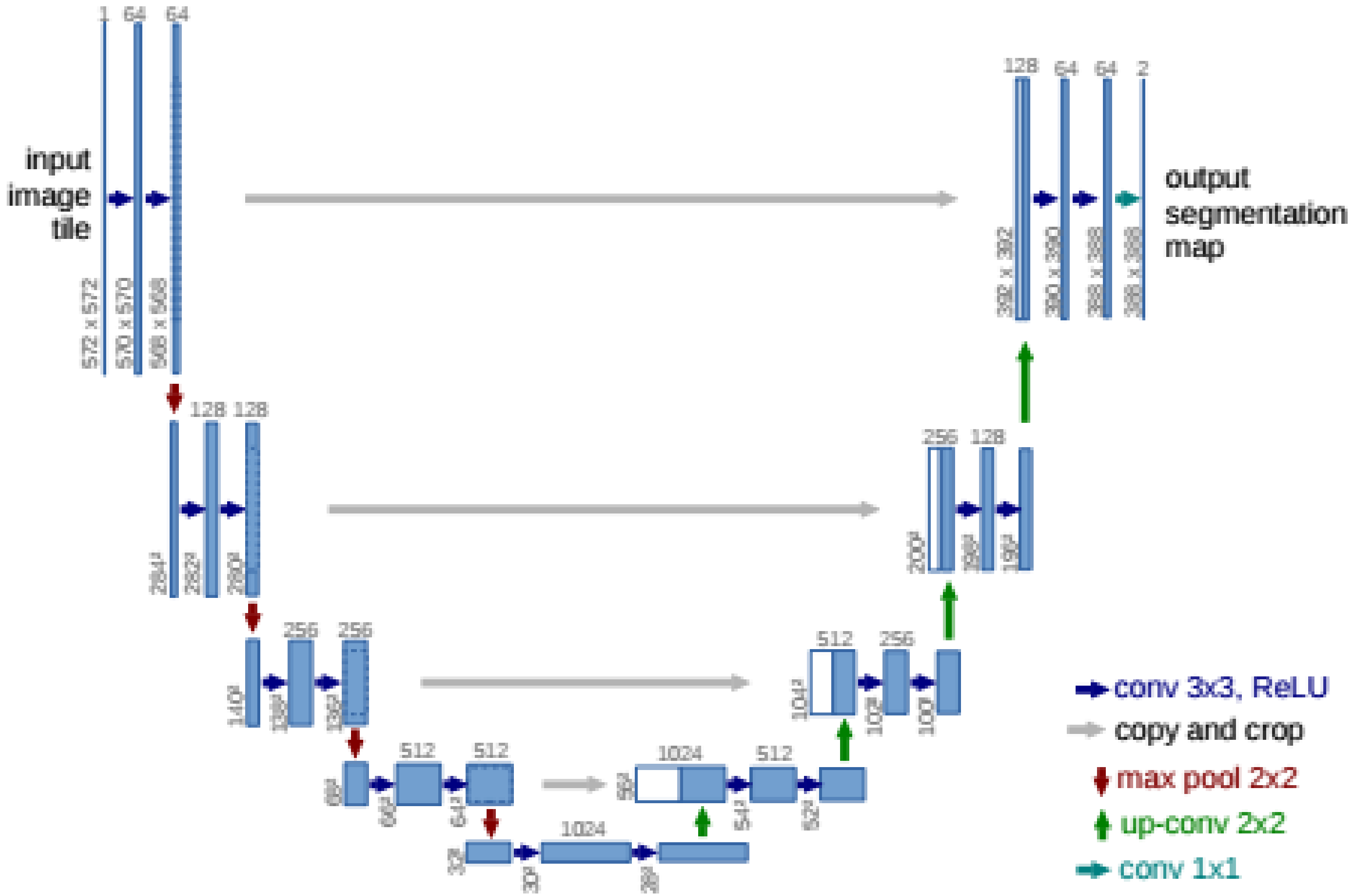
Traditionally segmentation done in a ‘patch’ based manner

- Gives pixel wise labelling
- Slow
- Trade-off between context and localization accuracy

Fully convolutional networks (FCN):

- Fully connected layers replaced by convolutional layers and add up-sampling layers
- End to end training
- Retains spatial information

# Network architecture



# Features

- Extensive data augmentation
  - ~30 training images
  - Random elastic deformations

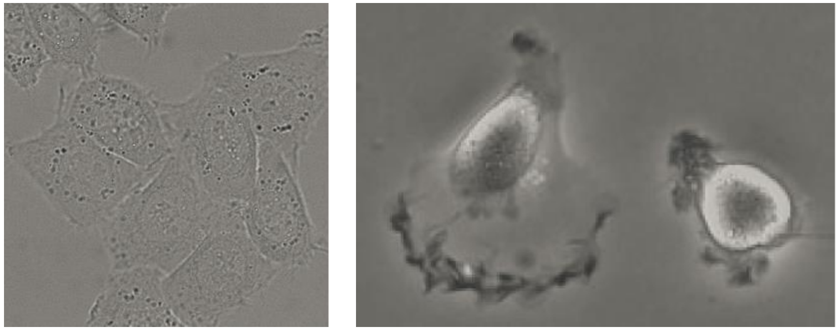


Fig. Sample images a) DIC HeLa cells b) Ph3-U373 dataset

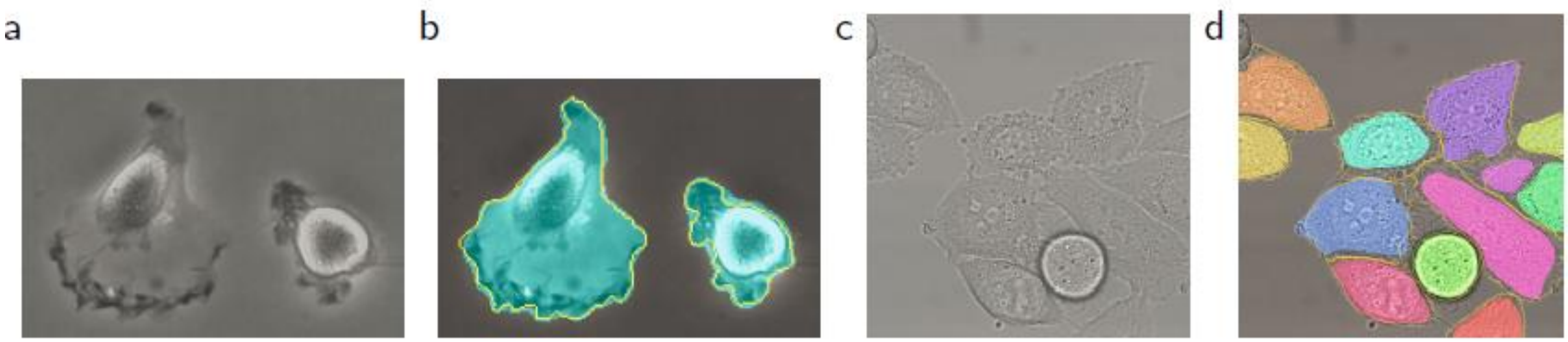
- Weighted loss
  - Balance different classes
  - Assign high weights to separating background pixels

$$w(\boldsymbol{x}) = w_c(\boldsymbol{x}) + w_0 \exp\left(-\frac{(d_1(\boldsymbol{x}) + d_2(\boldsymbol{x}))^2}{2\sigma^2}\right)$$

$wc : \Omega \rightarrow R$: weight map to balance the class frequencies,
$d1 : \Omega \rightarrow R$: distance to the border of the nearest cell
$d2 : \Omega \rightarrow R$: distance to the border of the second nearest cell

# Results

## ISBI cell tracking challenge 2015




(**a**) part of an input image of the "PhC-U373" data set. (**b**) Segmentation result (cyan mask) with manual ground truth (yellow border) (**c**) input image of the "DIC-HeLa" data set. (**d**) Segmentation result (random colored masks) with manual ground truth (yellow border).

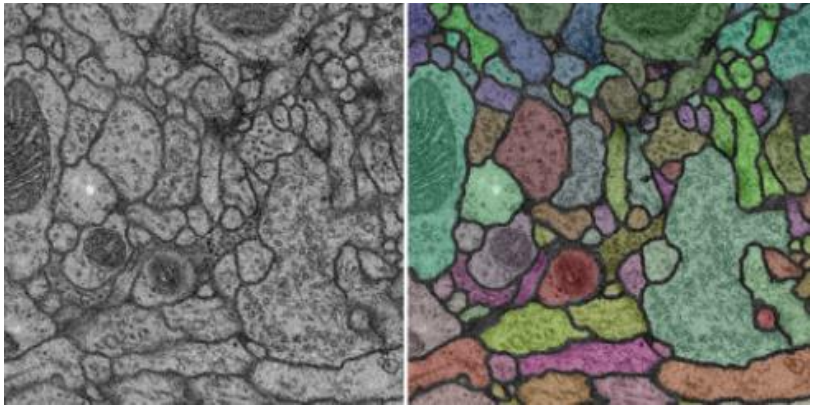
| Name | PhC-U373 | DIC-HeLa |
|---|---|---|
| IMCB-SG (2014) | 0.2669 | 0.2935 |
| KTH-SE (2014) | 0.7953 | 0.4607 |
| HOUS-US (2014) | 0.5323 | - |
| second-best 2015 | 0.83 | 0.46 |
| u-net (2015) | **0.9203** | **0.7756** |

Segmentation results (IOU) on the ISBI cell tracking challenge 2015

# Results

**ISBI EM segmentation challenge**

Sample image and ground truth



Ranking on the EM segmentation challenge [14] (march 6th, 2015), sorted by warping error.

| Rank | Group name | Warping Error | Rand Error | Pixel Error |
|---|---|---|---|---|
| | ** human values ** | 0.000005 | 0.0021 | 0.0010 |
| 1. | u-net | **0.000353** | 0.0382 | 0.0611 |
| 2. | DIVE-SCI | 0.000355 | 0.0305 | 0.0584 |
| 3. | IDSIA [2] | 0.000420 | 0.0504 | 0.0613 |
| 4. | DIVE | 0.000430 | 0.0545 | **0.0582** |
| ⋮ | | | | |
| 10. | IDSIA-SCI | 0.000653 | **0.0189** | 0.1027 |