Machine Learning in Dermatology: 2D Images, 3D Scans, and Regional Applications and Integrations

Jeremy Kawahara, PhD

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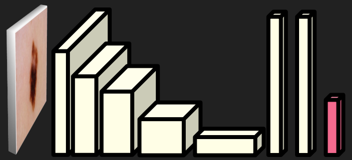
Background

PhD in Computing Science at **Simon Fraser University, Canada**

- **Medical Image Analysis Lab** @ SFU

Publishing works on **deep learning for dermatology** since **2016**



Working in industry developing a dermatology application used in Europe

SFU
SIMON FRASER UNIVERSITY

MIAL
Medical Image Analysis Lab

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Outline



Prior research

- 2D dermatology images
- Two works on full body 3D scans

Current work

- Dermatology application in Europe


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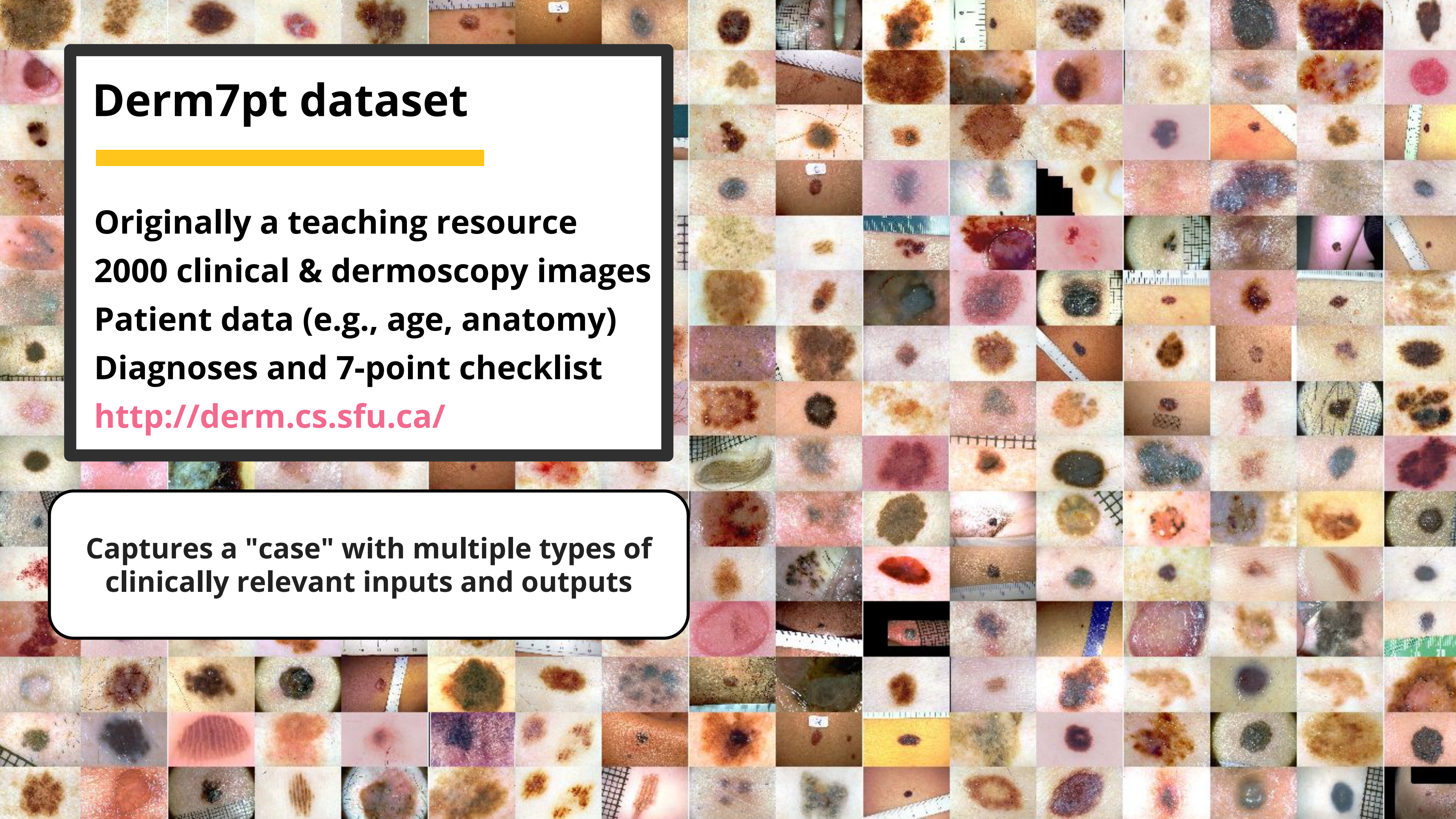


Derm7pt dataset

Originally a teaching resource
2000 clinical & dermoscopy images
Patient data (e.g., age, anatomy)
Diagnoses and 7-point checklist
http://derm.cs.sfu.ca/

Captures a "case" with multiple types of clinically relevant inputs and outputs

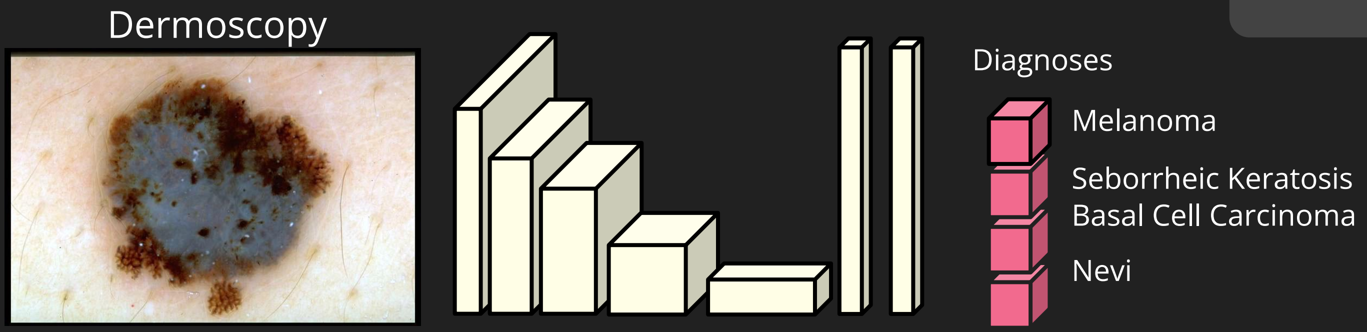
> IEEE J Biomed Health Inform. 2018 Apr 9. doi: 10.1109/JBHI.2018.2824327. Online ahead of print.

7-Point Checklist and Skin Lesion Classification using Multi-Task Multi-Modal Neural Nets

Jeremy Kawahara, Sara Daneshvar, Giuseppe Argenziano, Ghassan Hamarneh

Corresponding paper with data

Architecture designed with this data in mind



Start with a standard CNN to predict the diagnosis from the image

Extend **architecture** to handle **multiple** types of inputs and outputs

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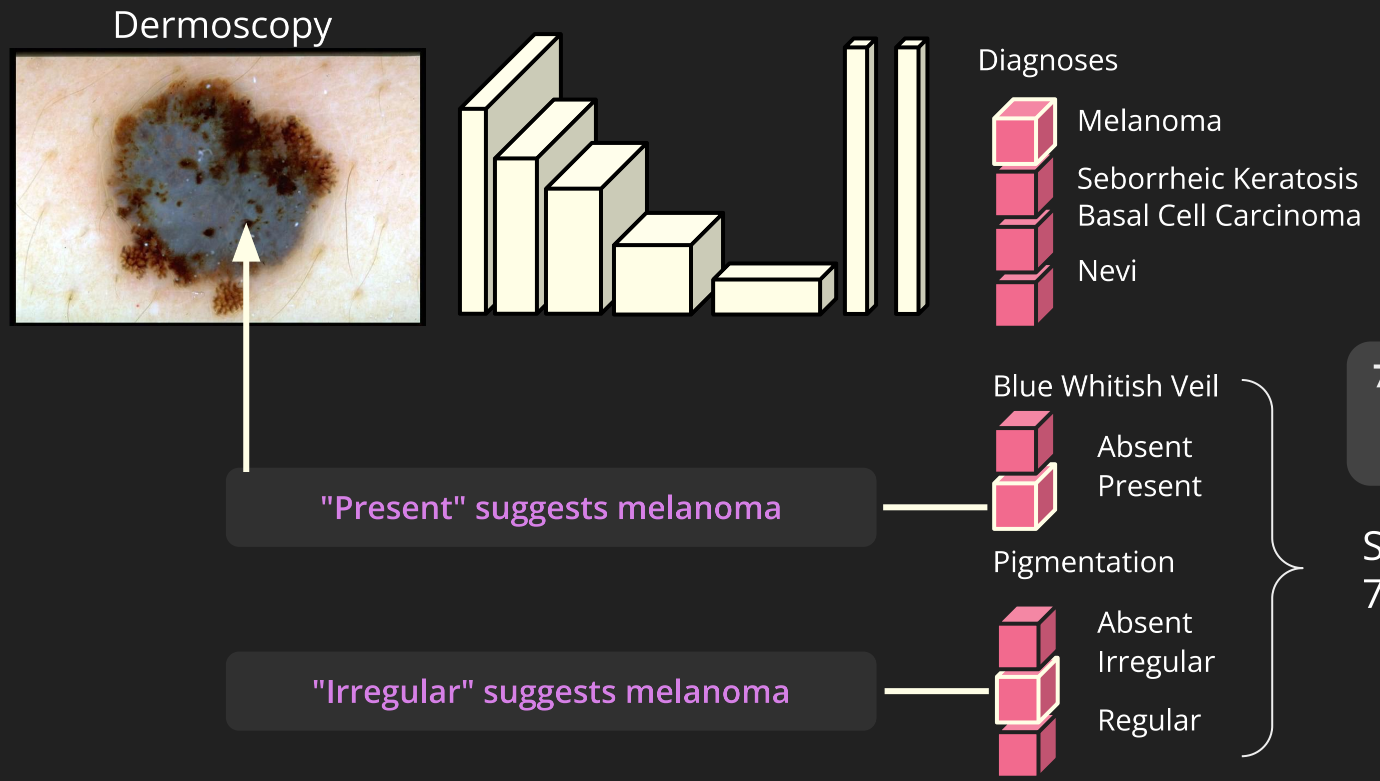

Other types of relevant outputs

7-point contains checklist items that are related to melanoma

Showing 2 of the 7 checklist items

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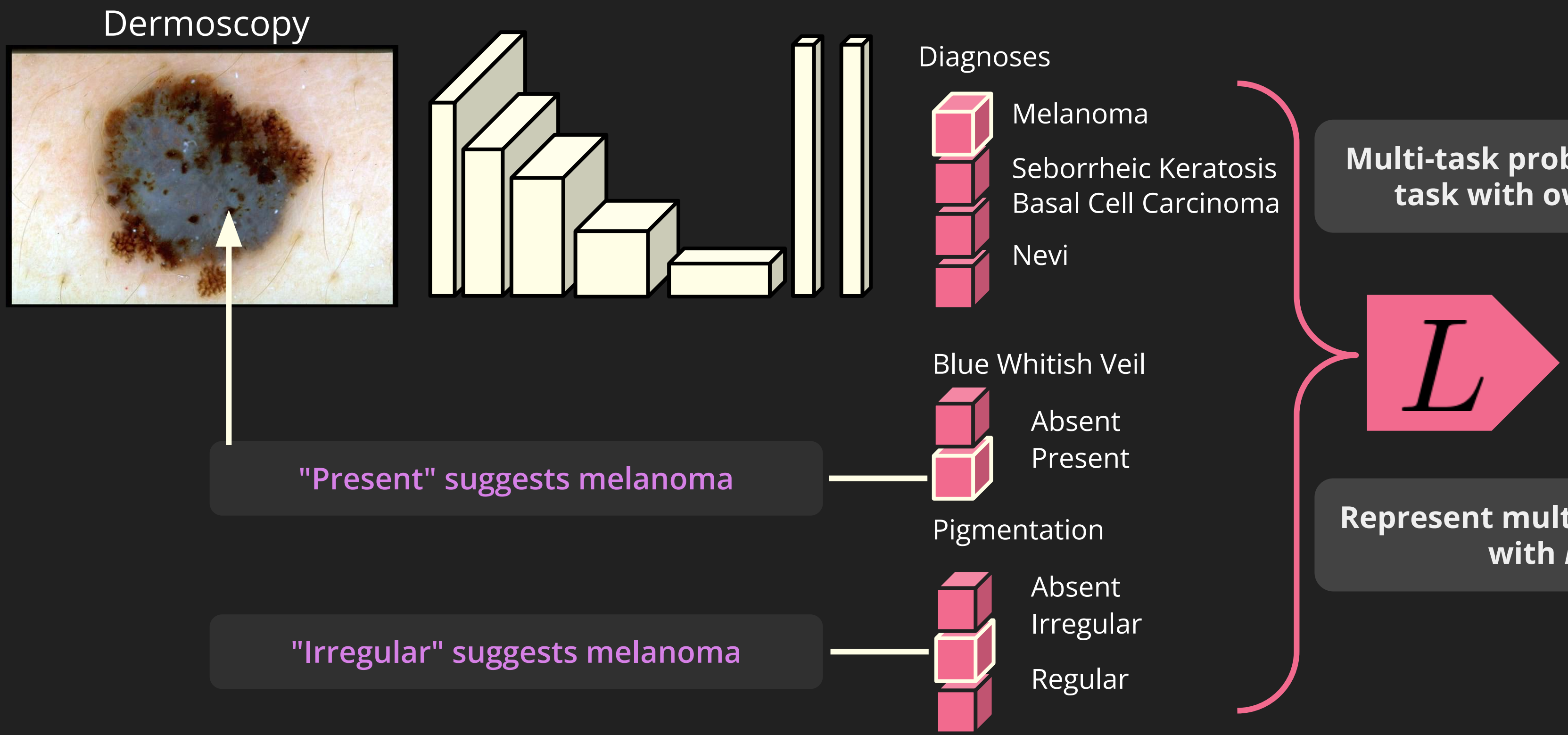

Multi-task problem: Each task with own loss

Represent multiple losses with L

IEEE J Biomed Health Inform. 2018 Apr 9. doi: 10.1109/JBHI.2018.2824327. Online ahead of print.

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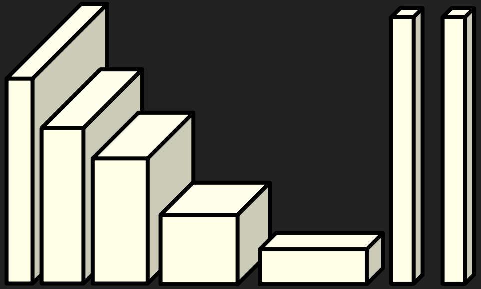
Dermoscopy



Predictions should be a function of all the input data

Patient age, sex, anatomy

Clinical/Macroscopic

Other types of inputs

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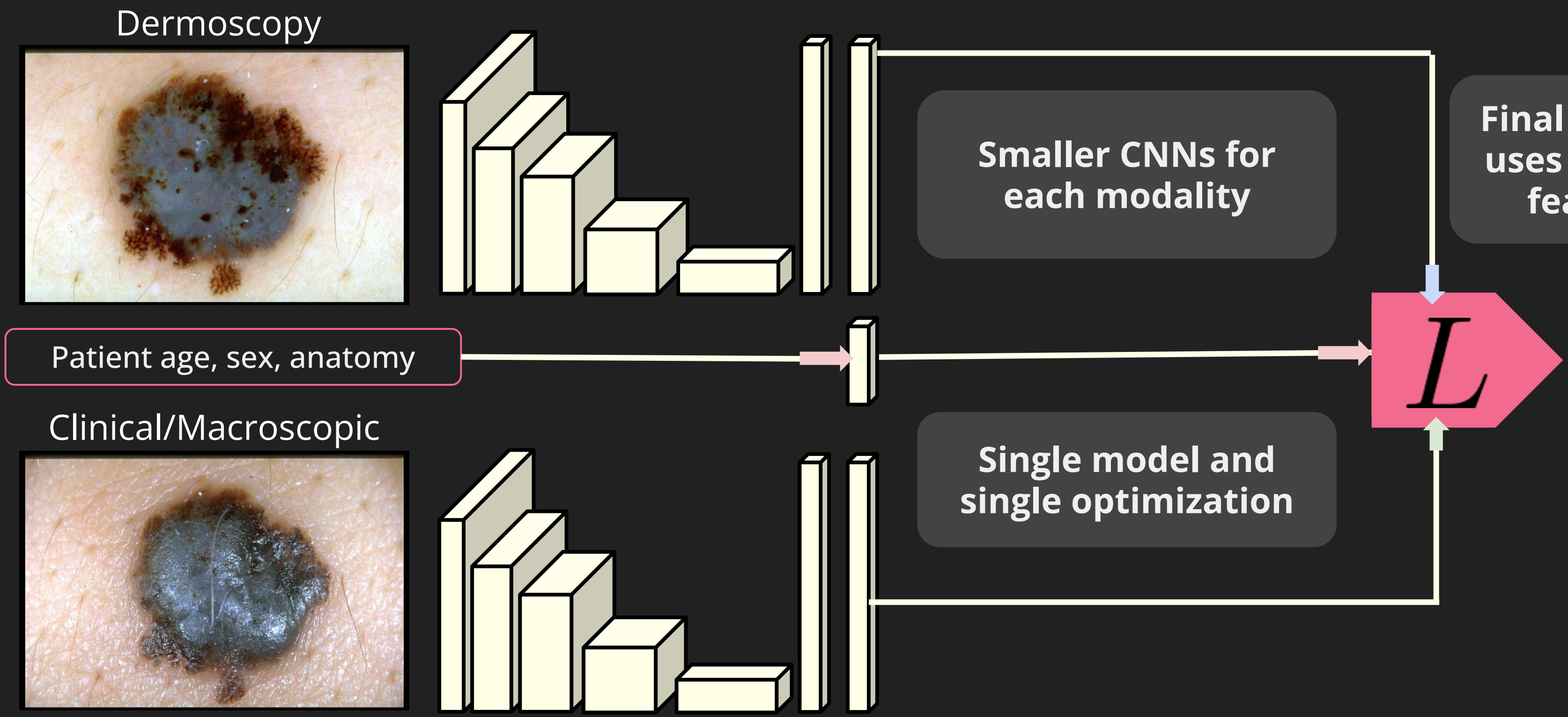
Extend architecture to jointly train and learn relationships across all inputs



Smaller CNNs for each modality

Final network uses all input features

Single model and single optimization

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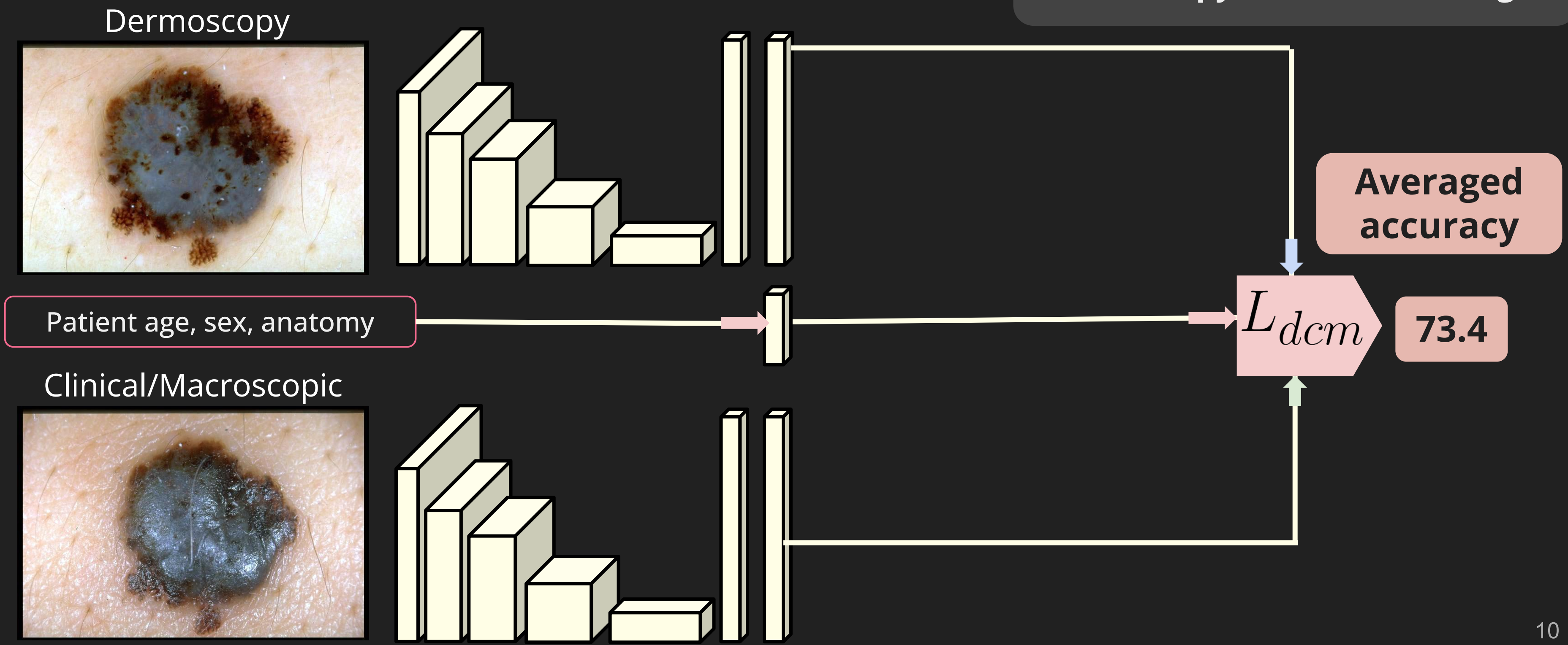
Predictions using patient info, dermoscopy, and clinical images



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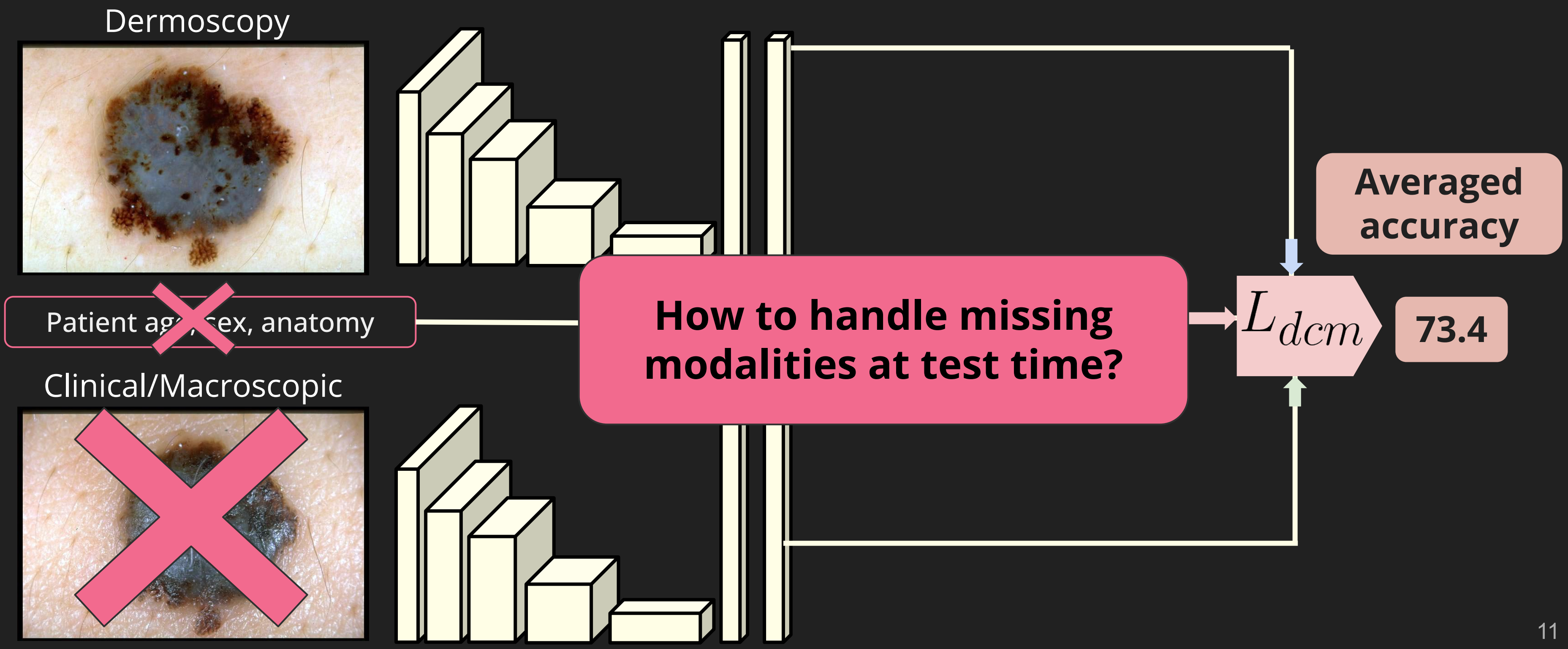

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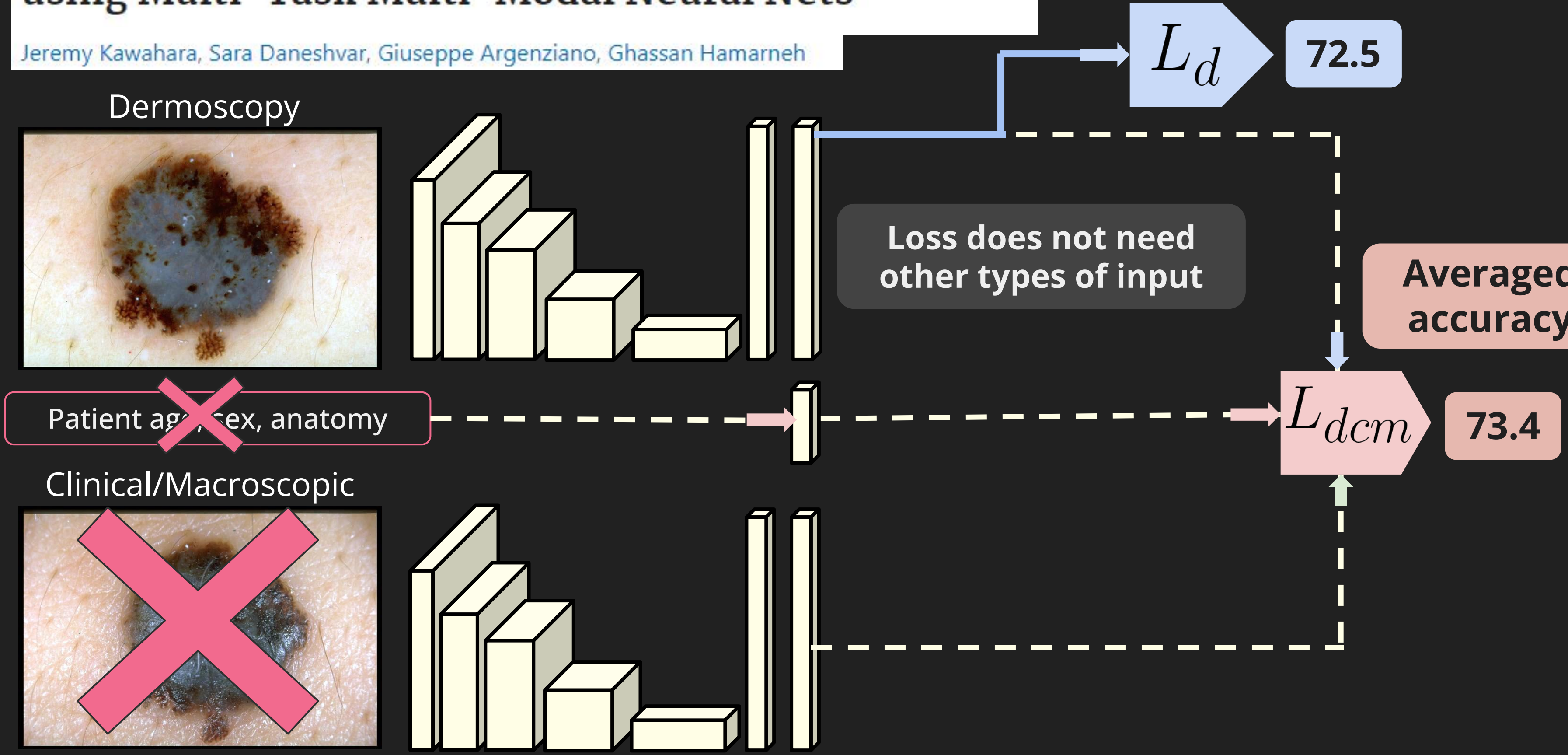
Add dermoscopy only loss

Loss does not need other types of input

Averaged accuracy



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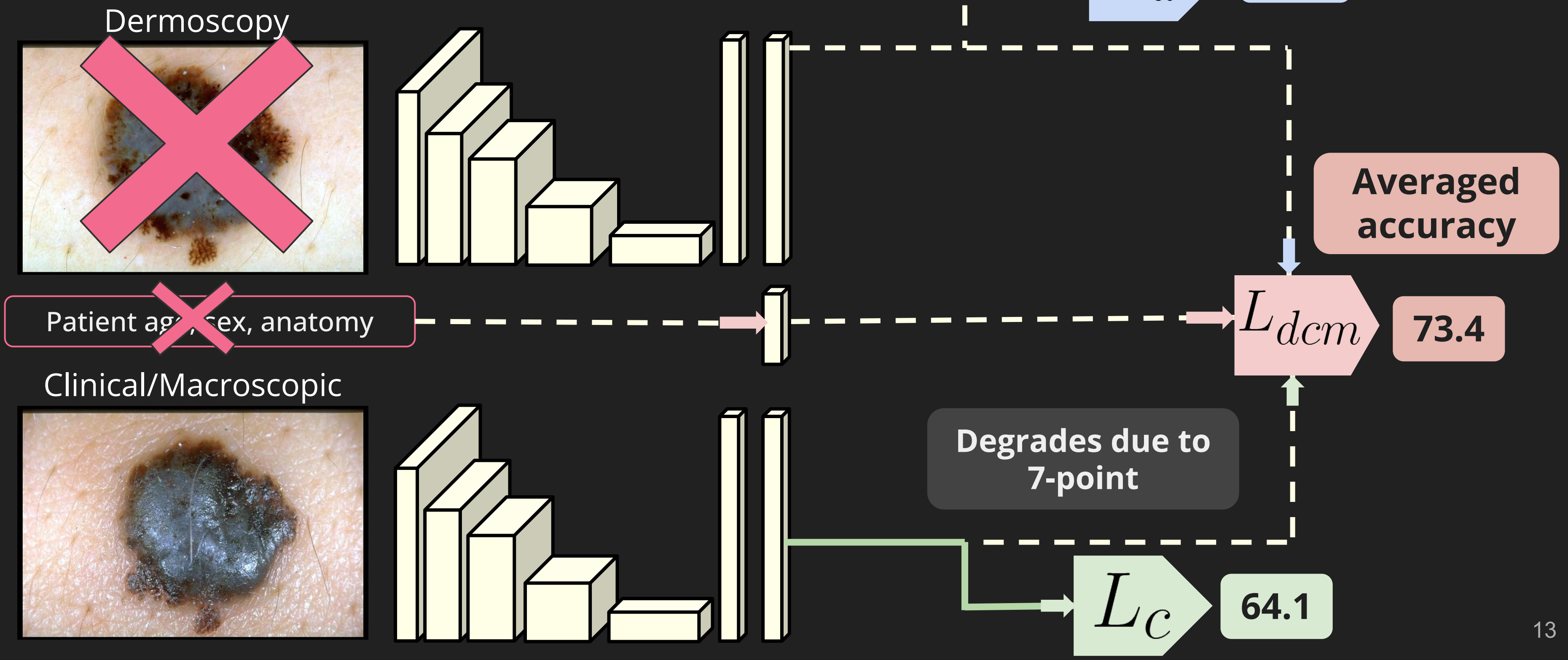

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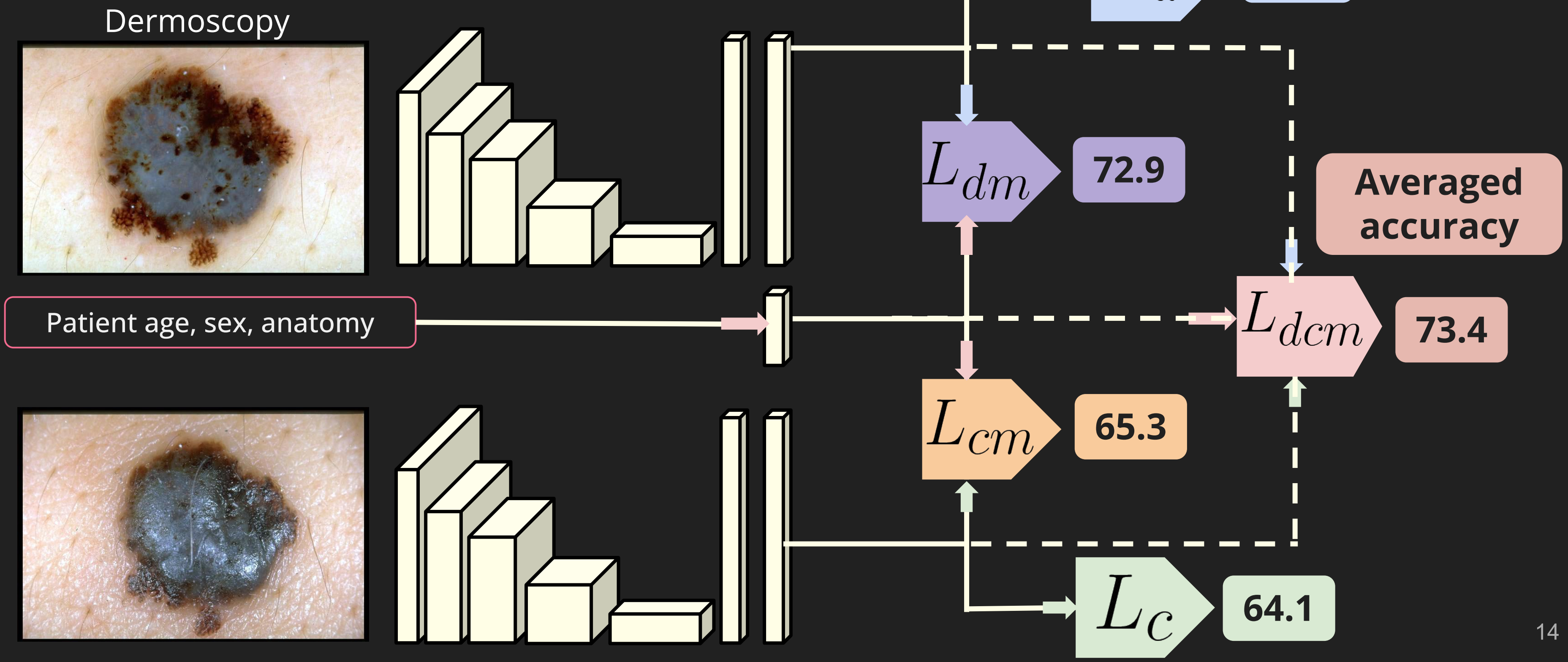
Using all input data yields highest performance

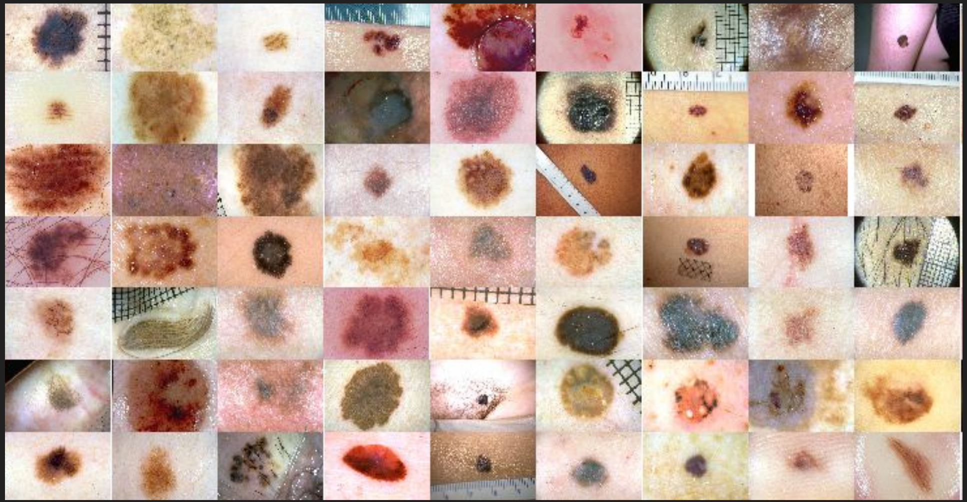


From 2D to 3D skin image analysis

Clinical/macroscopic

Dermatoscope

Derm7pt: 2D clinical and dermoscopy images



Canfield VECTRA WB360

3D scans of the human body

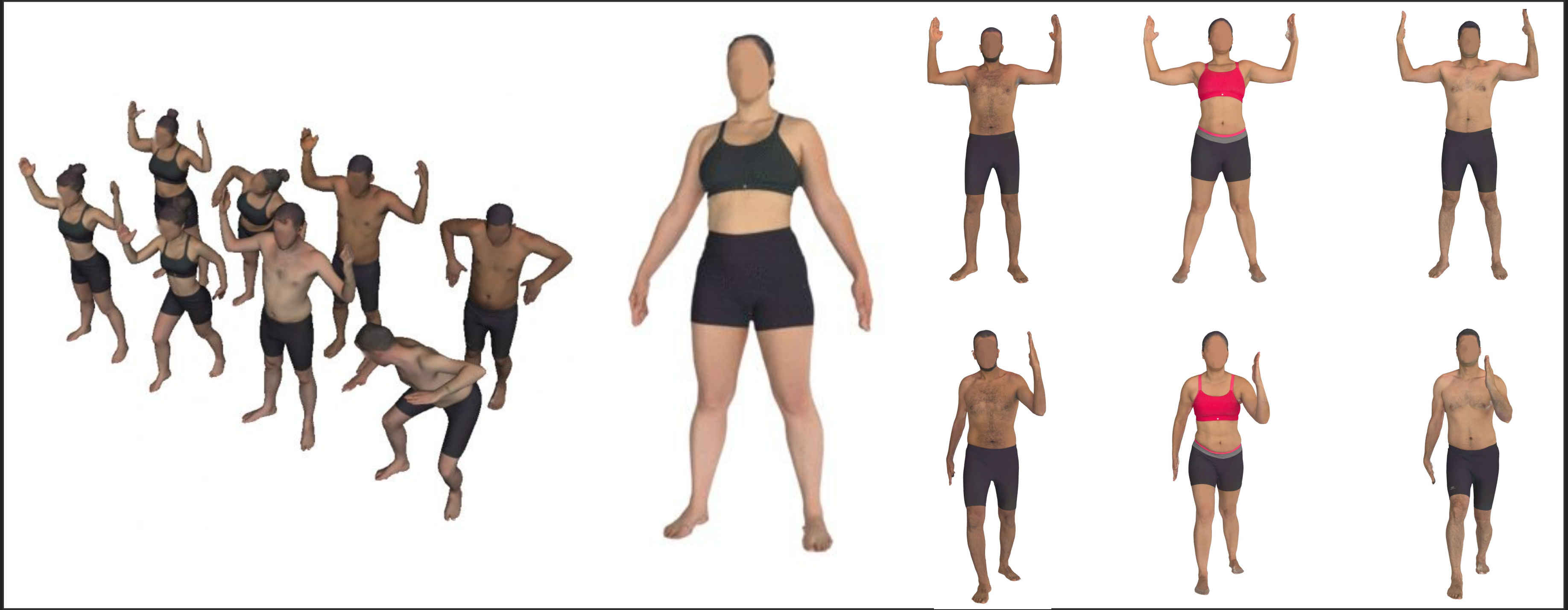
3DBodyTex

3DBodyTex: Textured 3D Body Dataset

SAINT, Alexandre Fabian A ; AHMED, Eman ; SHABAYEK, Abd El Rahman *et al.*

2018 • In *2018 Sixth International Conference on 3D Vision (3DV 2018)*

200 subjects: 100 males and 100 females in two poses each

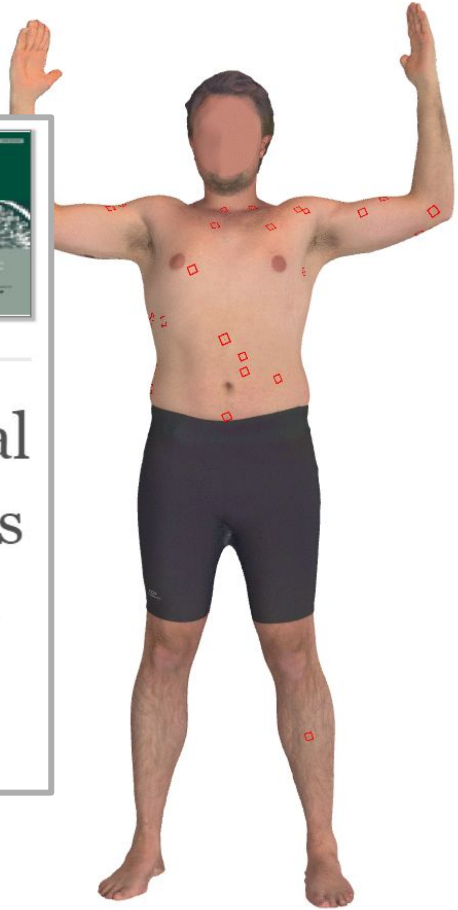


https://cvi2.uni.lu/3dbodytexv1/

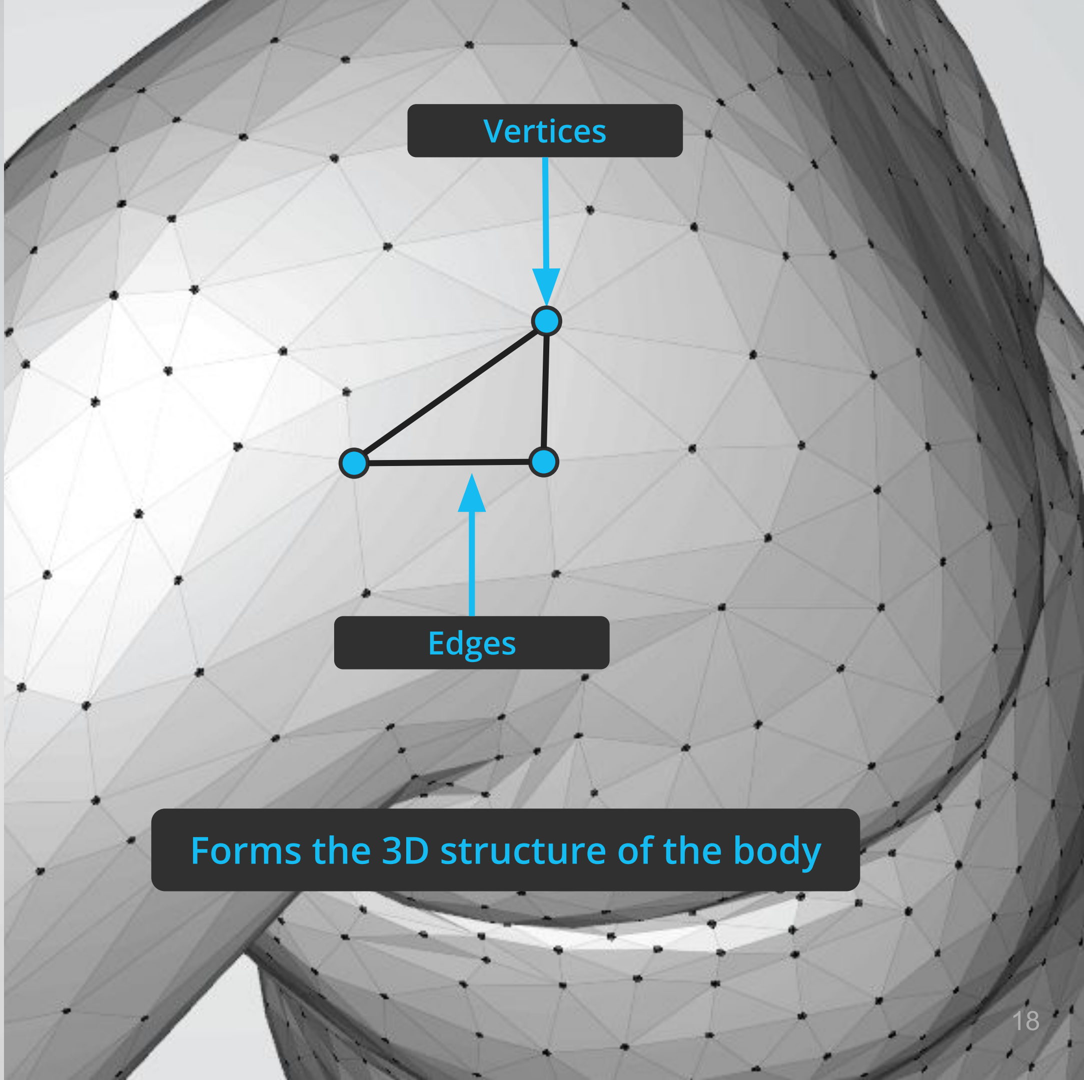
Medical Image Analysis
Available online 30 December 2021, 102329
In Press, Journal Pre-proof

Skin3D: Detection and Longitudinal Tracking of Pigmented Skin Lesions in 3D Total-Body Textured Meshes

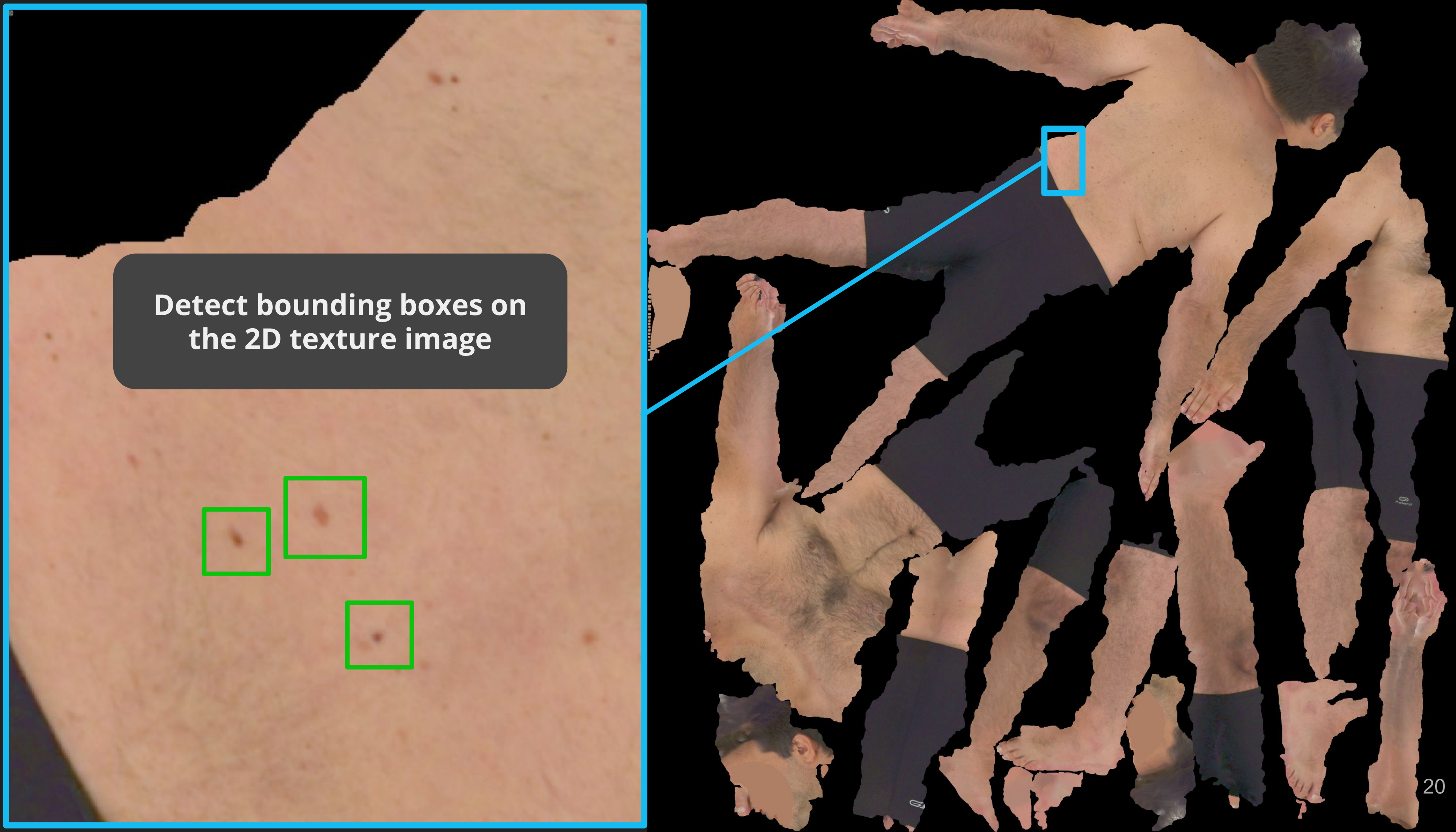
Mengliu Zhao [1, a], Jeremy Kawahara [1, a], Kumar Abhishek [a], Sajjad Shamanian [a], Ghassan Hamarneh [a]

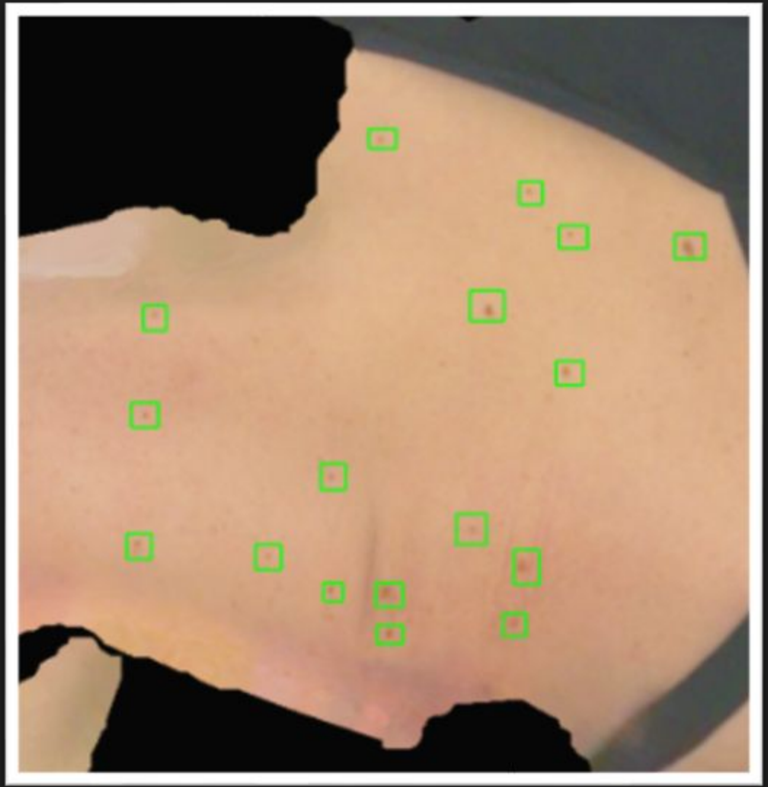


Goal: Place a bounding box around moles on the 3D body


Vertices
Edges
Forms the 3D structure of the body

2D texture image maps to the 3D body

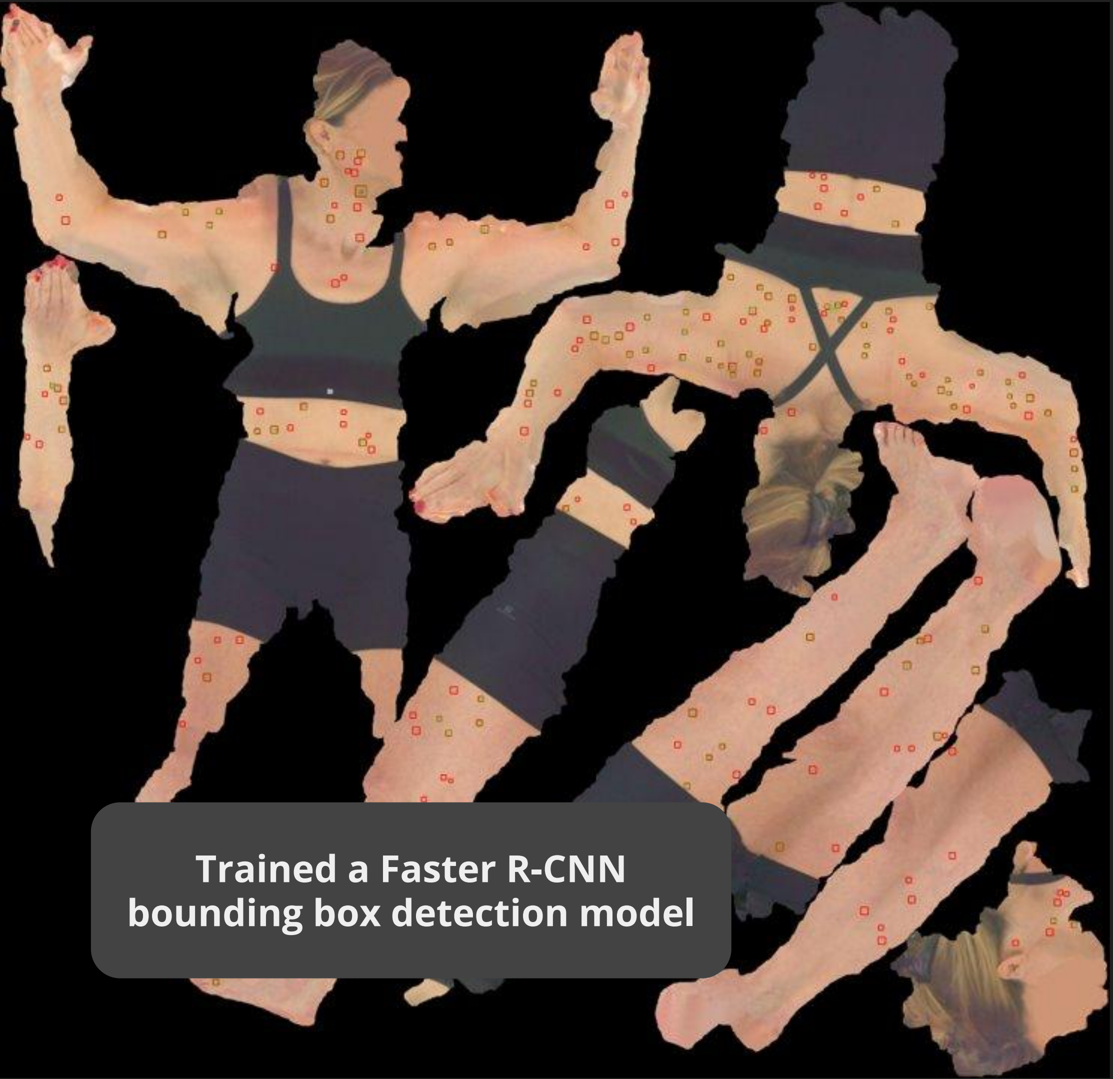

Detect bounding boxes on
the 2D texture image



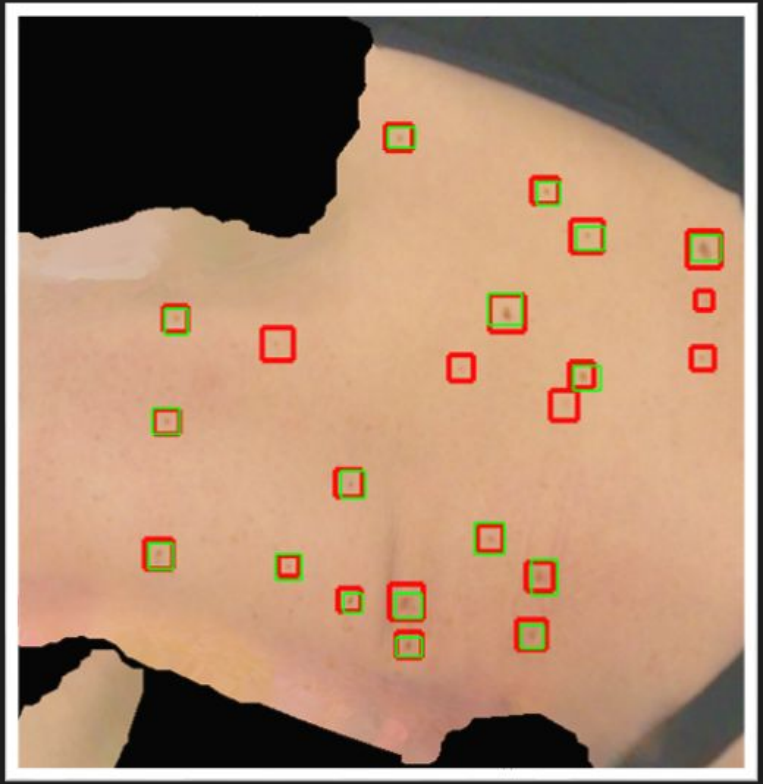
Require annotated data

Manually annotated
~25,000 bounding boxes

https://www.robots.ox.ac.uk/~vgg/software/via/



Trained a Faster R-CNN bounding box detection model



Green = Human annotations

Red = Machine predicted annotations

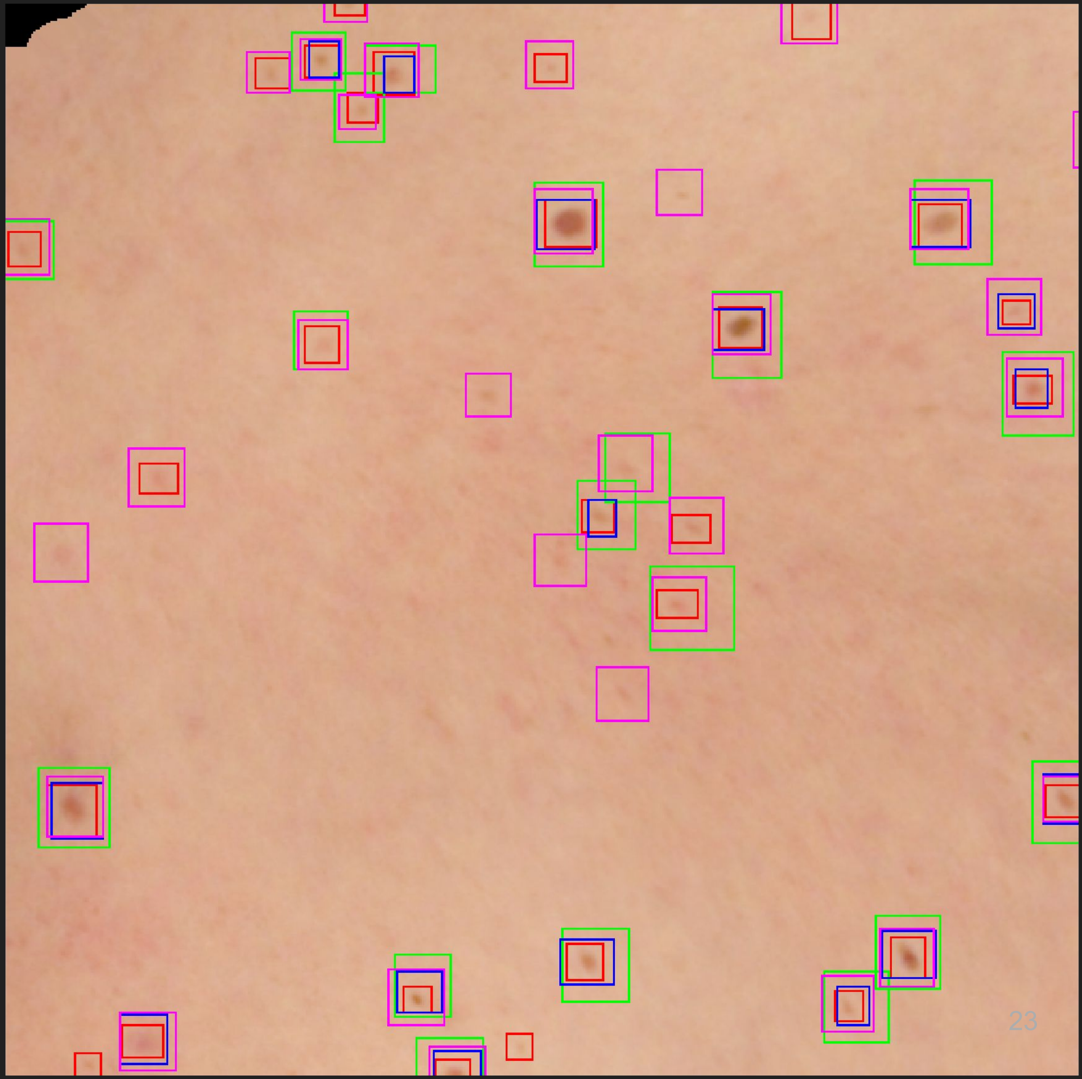
Evaluations

Machine predictions compared with a single human annotator

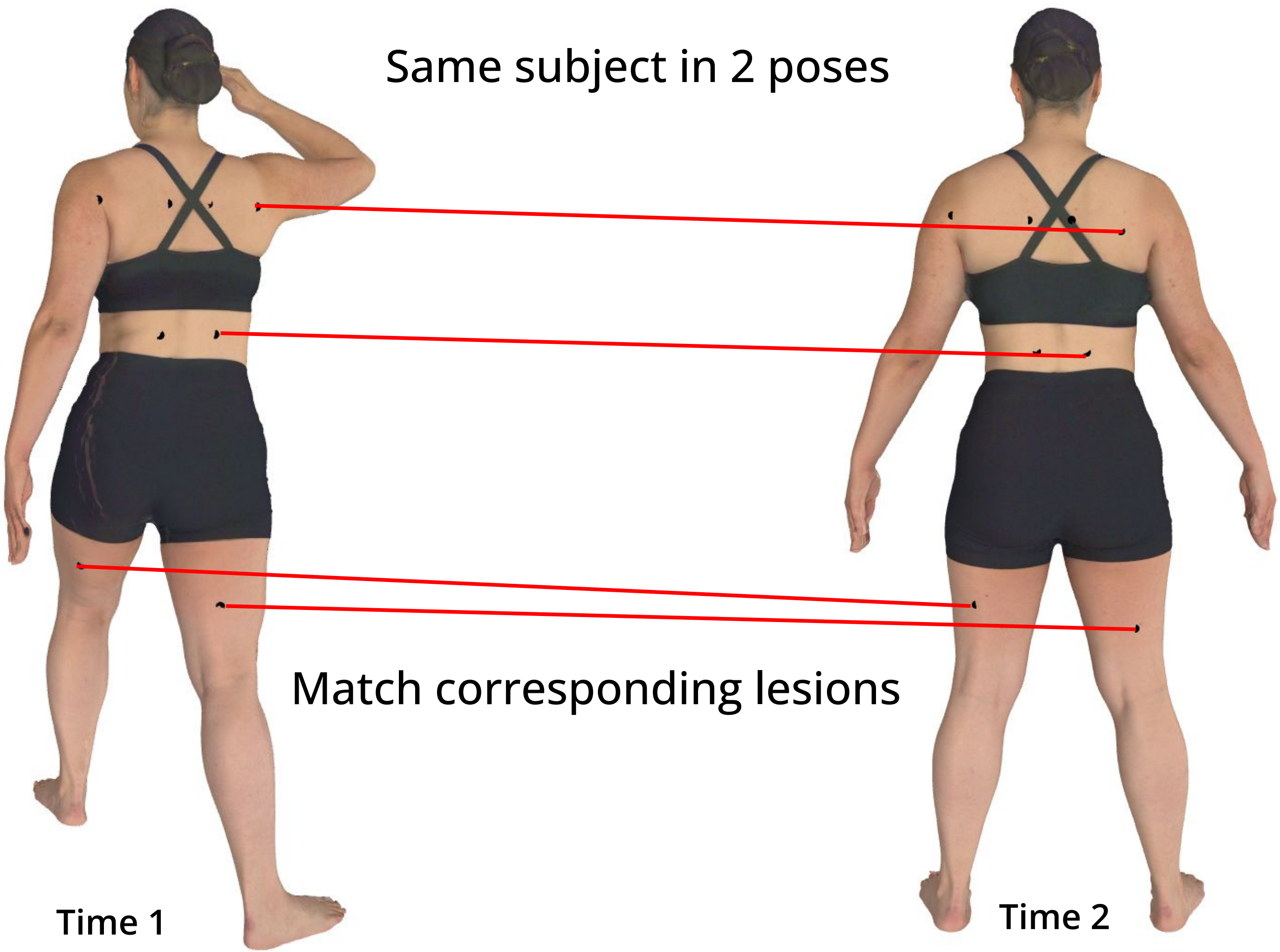
Recall	Precision
0.84	0.66

Inter-annotator performance

2 out of 3 human annotators agreed more with the machine annotations than any other human



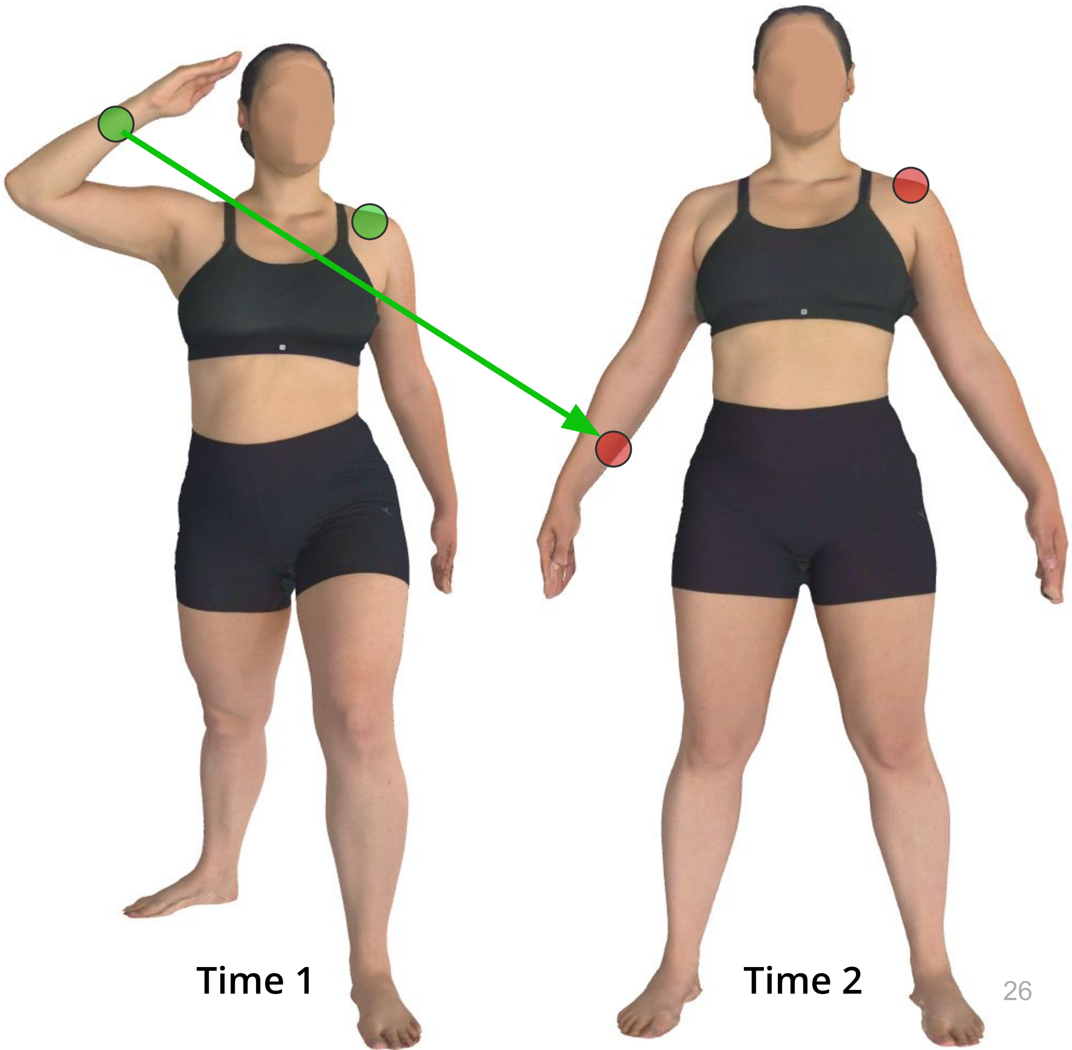
Map the 2D detected lesions back to the 3D body


Same subject in 2 poses
Match corresponding lesions
Time 1
Time 2

Matching Lesions

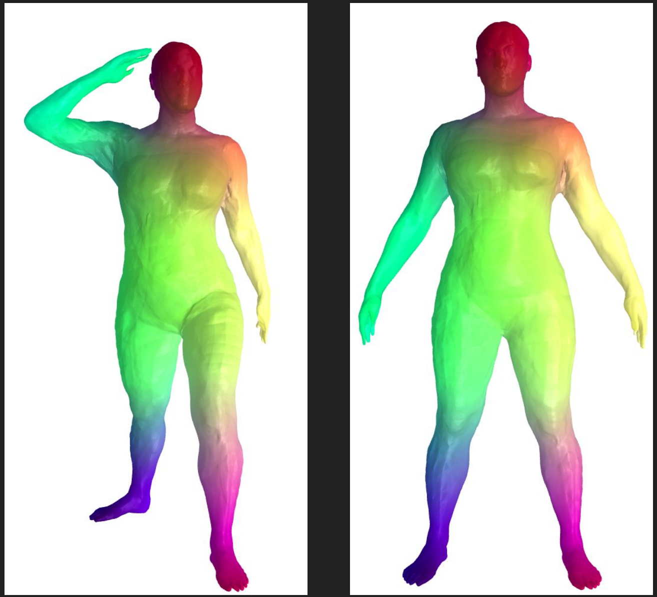
Same subject, two scans

Two lesions we want to track across scans



Matching Lesions

3D vertex correspondence
using a common template



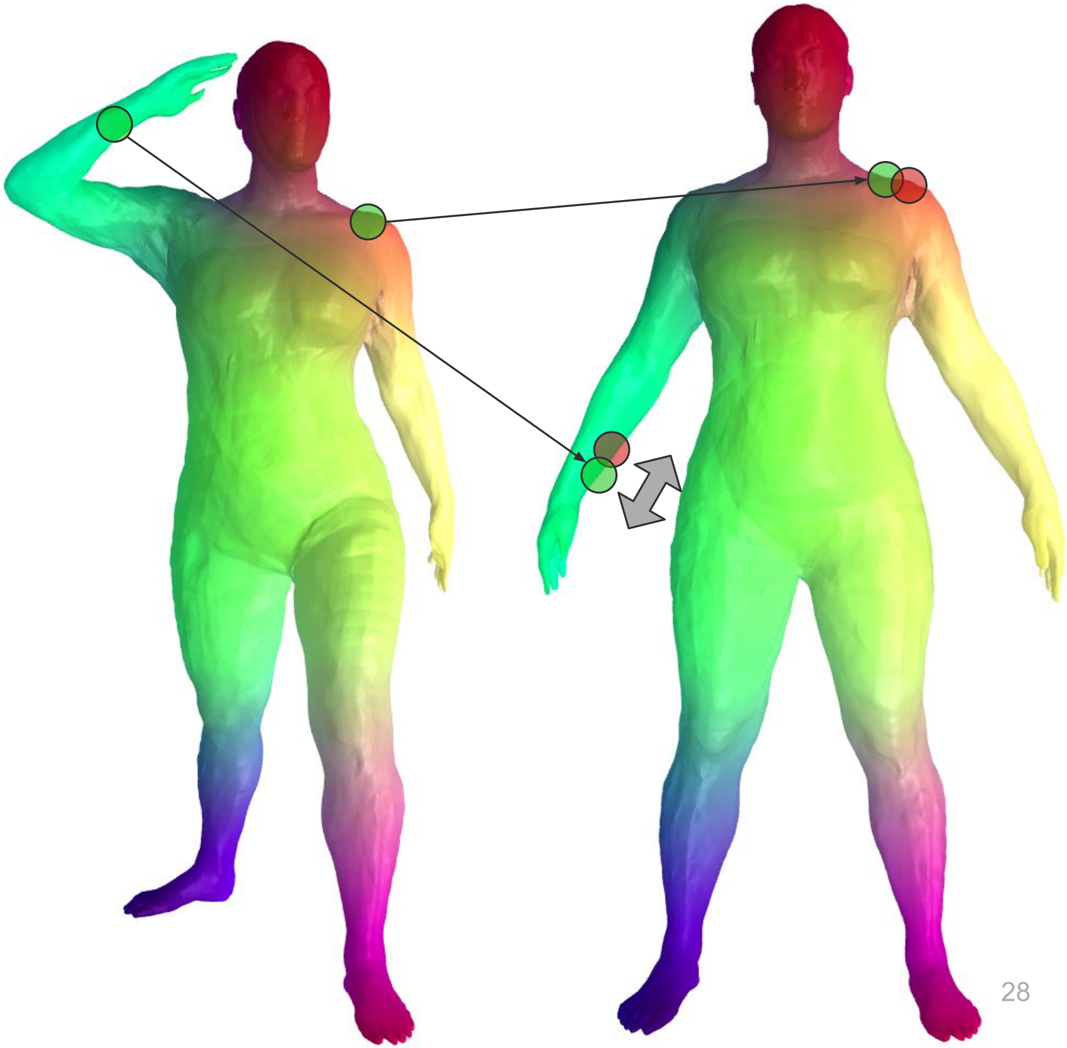
3D-CODED: 3D Correspondences by Deep Deformation. Groueix et. al., ECCV, 2018.

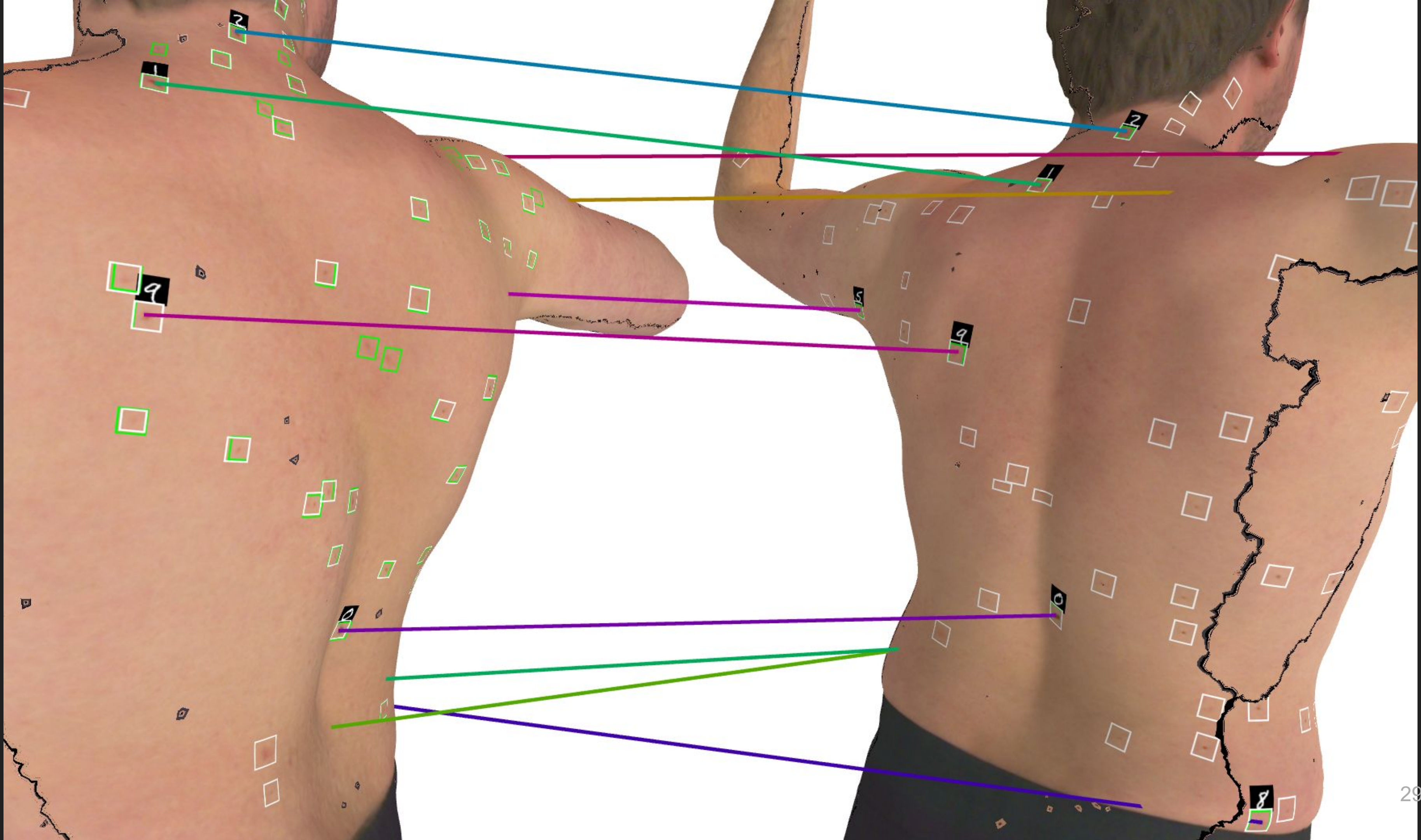
Matching Lesions

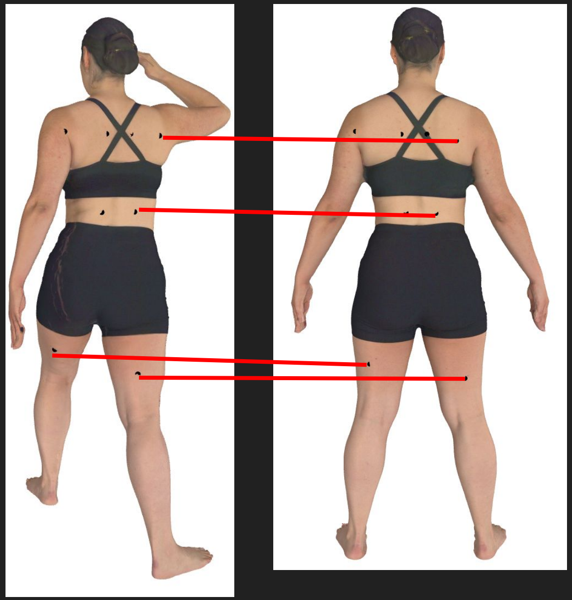
Map lesion to corresponding vertex on other scan

Compare the geodesic distance between lesions on the same mesh

Closer mapped lesions indicate the same lesion




2
1
9
0
2
1
5
9
0
8



Skin3D: bounding boxes on 3D meshes
https://github.com/jeremykawahara/skin3d

- **25,000** bounding boxes
- **200** subjects from 3DBodyTex
- Matched a subset of lesions across scans

ELSEVIER
Medical Image Analysis
Volume 95, July 2024, 103145

DermSynth3D: Synthesis of in-the-wild annotated dermatology images

Ashish Sinha [a 1], Jeremy Kawahara [a 1], Arezou Pakzad [a 1], Kumar Abhishek [a], Matthieu Ruthven [b], Enjie Ghorbel [b c], Anis Kacem [b], Djamila Aouada [b], Ghassan Hamarneh [a]

Real lesion on 2D image

3D body scan

2D lesion transferred to 3D body

Maintain lesion appearance while blending well on the 3D body

2D view

Potential application:
Synthesize 2D image datasets for machine learning tasks

DermSynth3D: Synthesis of in-the-wild annotated dermatology images

Ashish Sinha [a 1], Jeremy Kawahara [a 1], Arezou Pakzad [a 1], Kumar Abhishek [a], Matthieu Ruthven [b], Enjie Ghorbel [b c], Anis Kacem [b], Djamila Aouada [b], Ghassan Hamarneh [a]

3D body scan

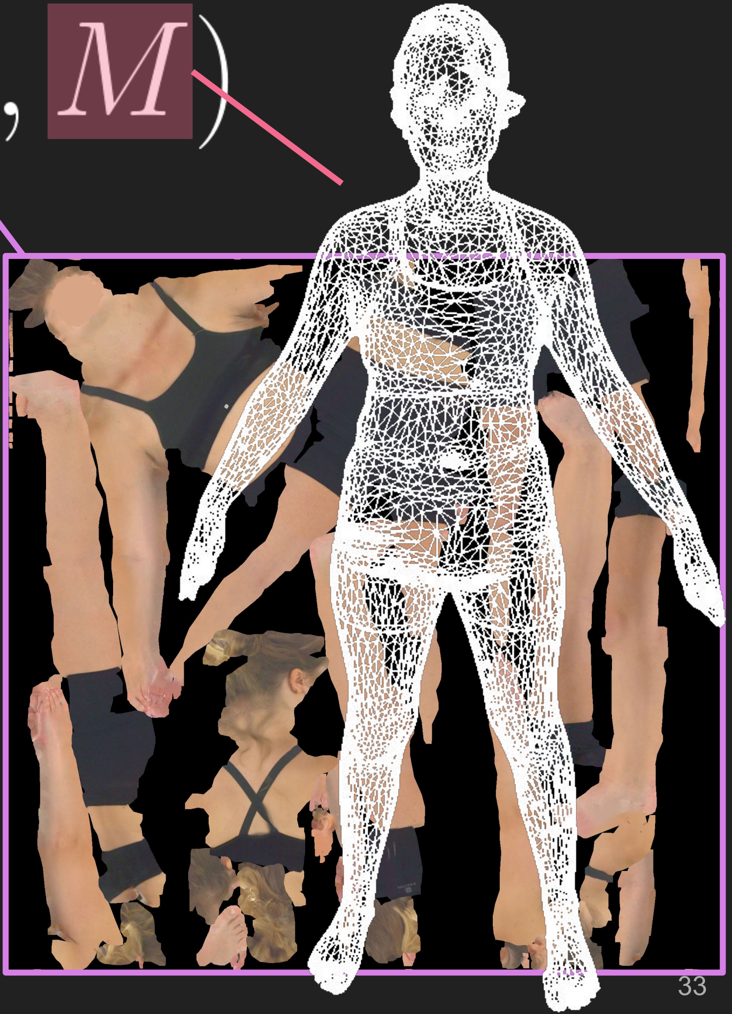
2D lesion transferred to 3D body

2D annotations

Rendering

$$x = R(\kappa, \boxed{T}, \boxed{M})$$

3D body

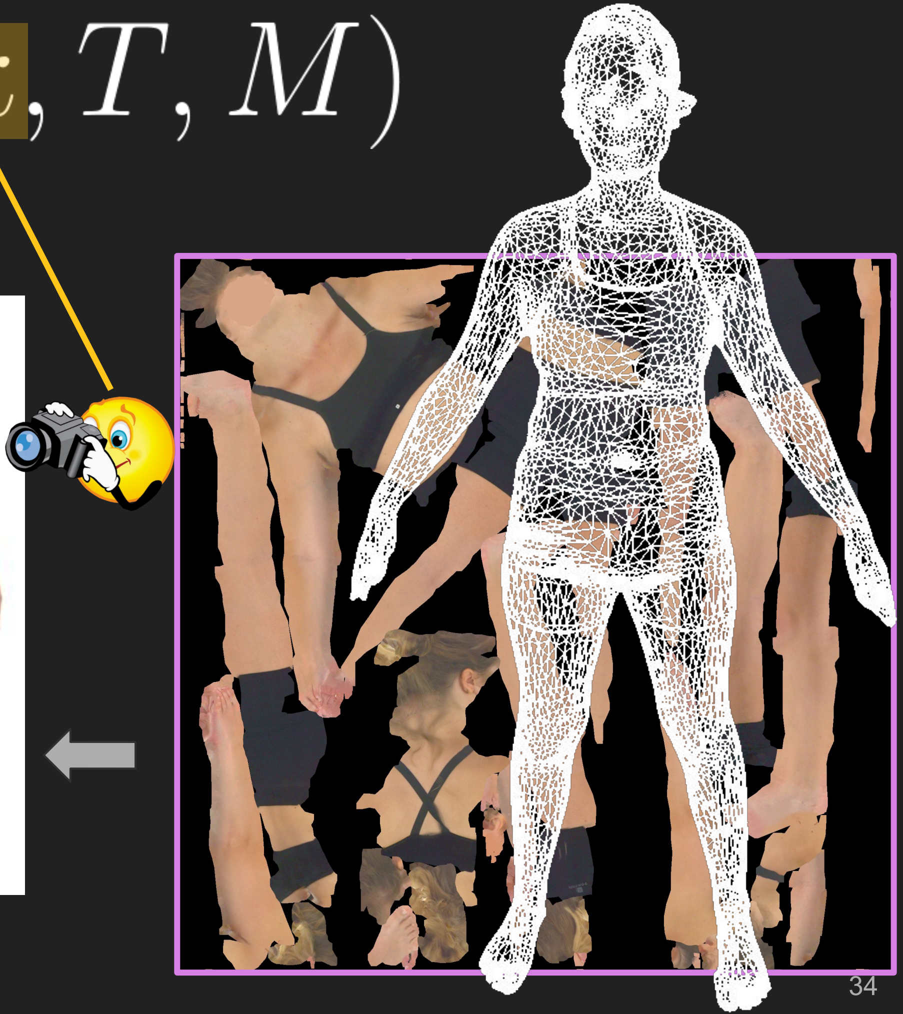


Rendering

$$\boxed{x} = R\left(\boxed{\kappa}, T, M\right)$$

Rendered 2D image

3D body

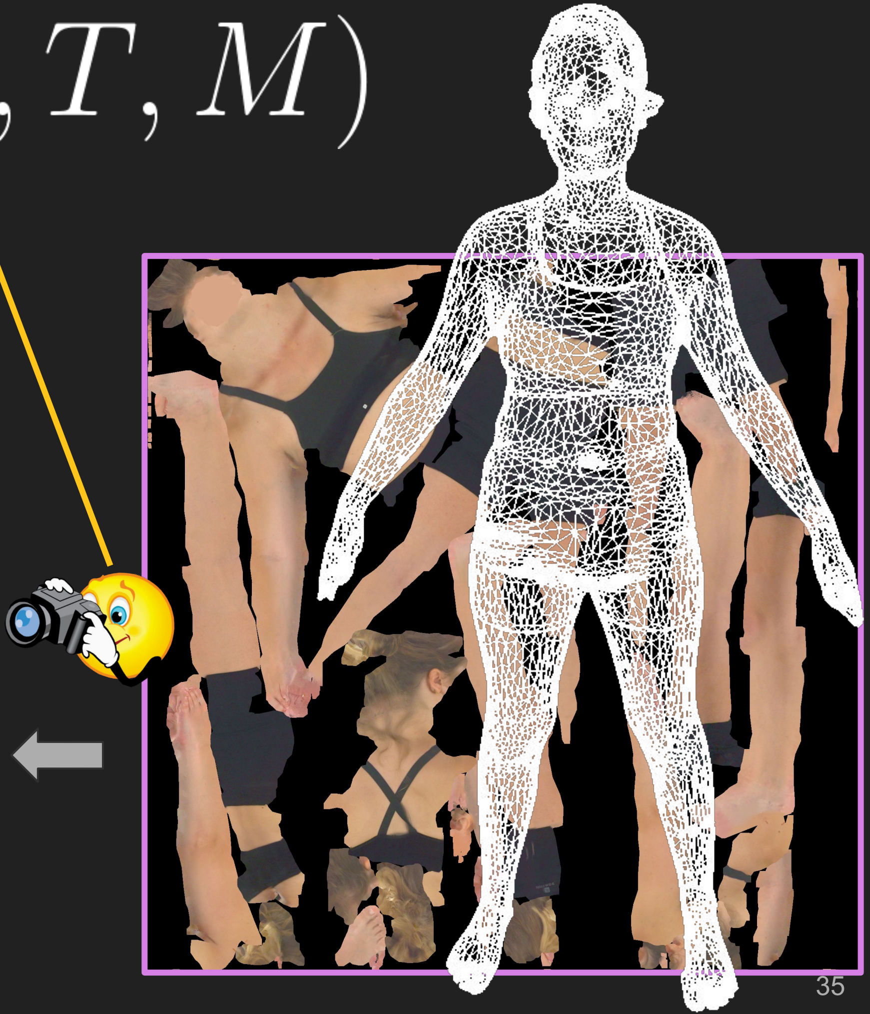


Rendering

$$\boxed{x} = R\left(\boxed{\kappa}, T, M\right)$$


Rendered 2D image


3D body



Differentiable Rendering

$$x = \boxed{R}(\kappa, T, M)$$

Backpropagate to ***T***

$$L(x)$$

Rendered 2D image

Will see why important
in a few slides

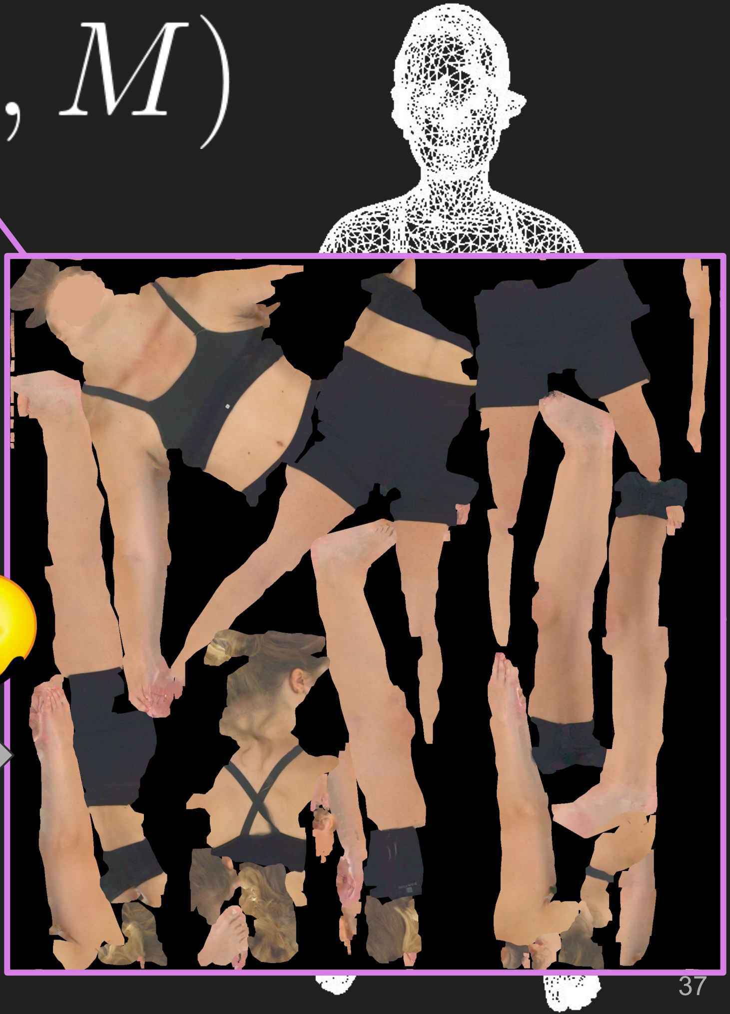
3D body

Differentiable Rendering

$$\boxed{x} = R\left(\kappa, \boxed{T}, M\right)$$

Rendered 2D image

3D body

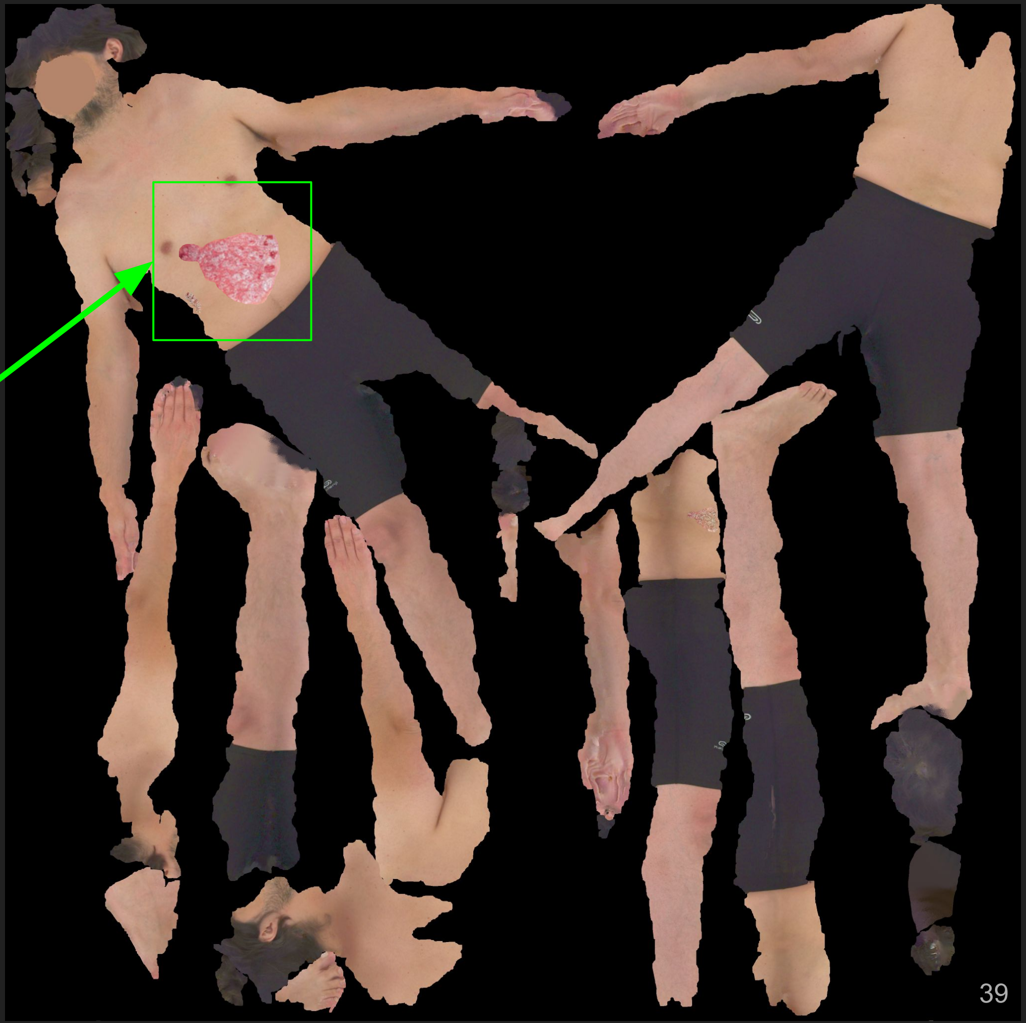


Transfer Real Lesion onto Texture Image?

Real segmented lesion

Would render on the 3D body

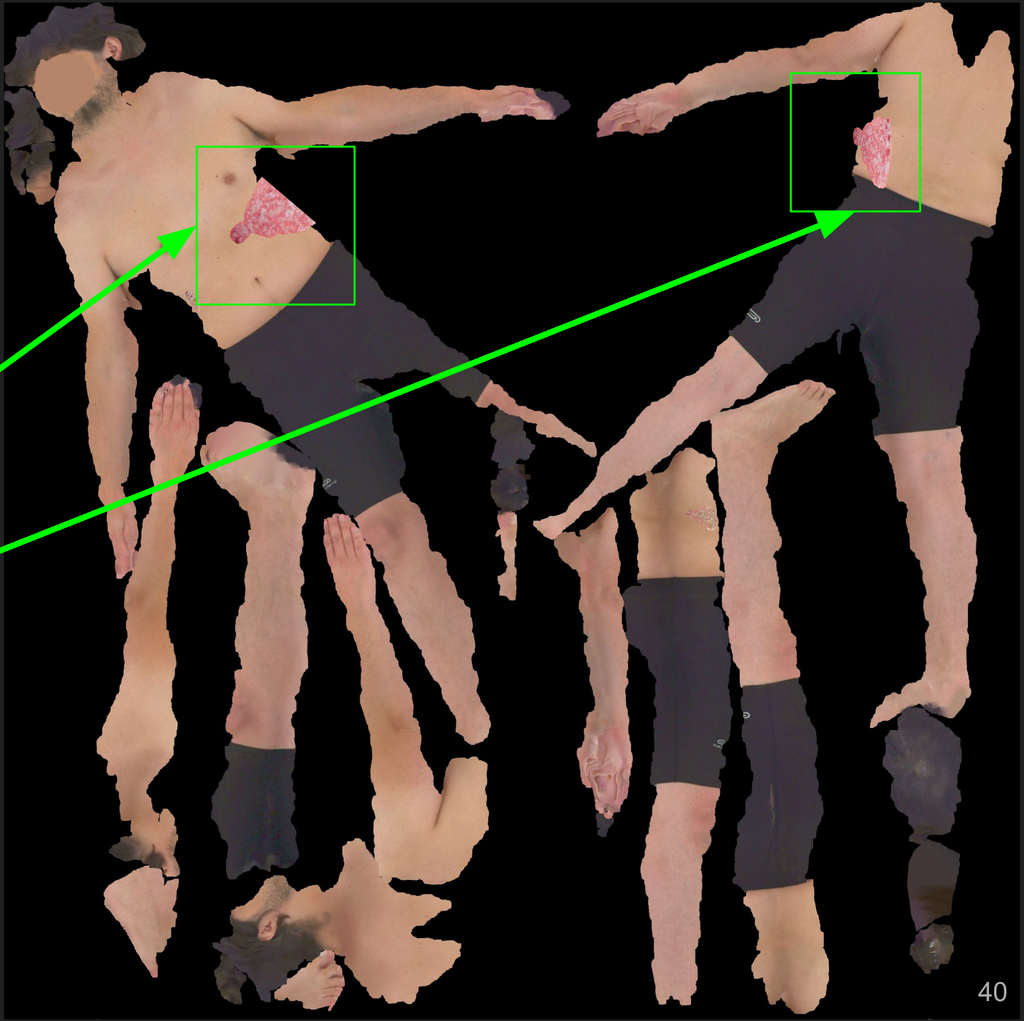
Real segmented lesion



Would render on the 3D body

But placing the lesions is a challenge due to seams

Real segmented lesion



Blending Lesions

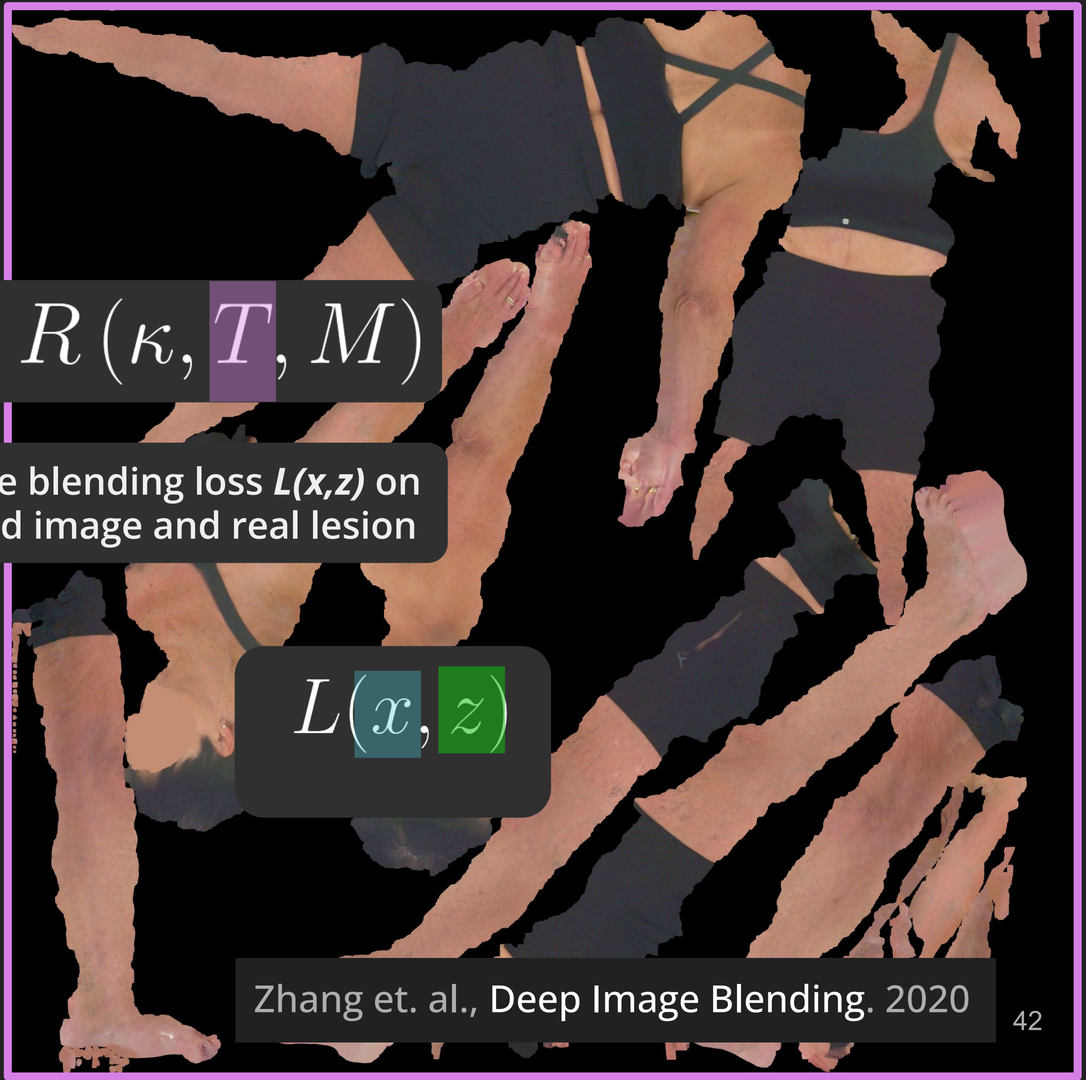
Rendered image

$$x = R(\kappa, T, M)$$

Blending Lesions

Rendered image

Segmented real lesion



$$x = R(\kappa, T, M)$$

Compute blending loss ***L(x,z)*** on rendered image and real lesion

$$L(x, z)$$

Zhang et. al., Deep Image Blending. 2020

Blending Lesions

Rendered image

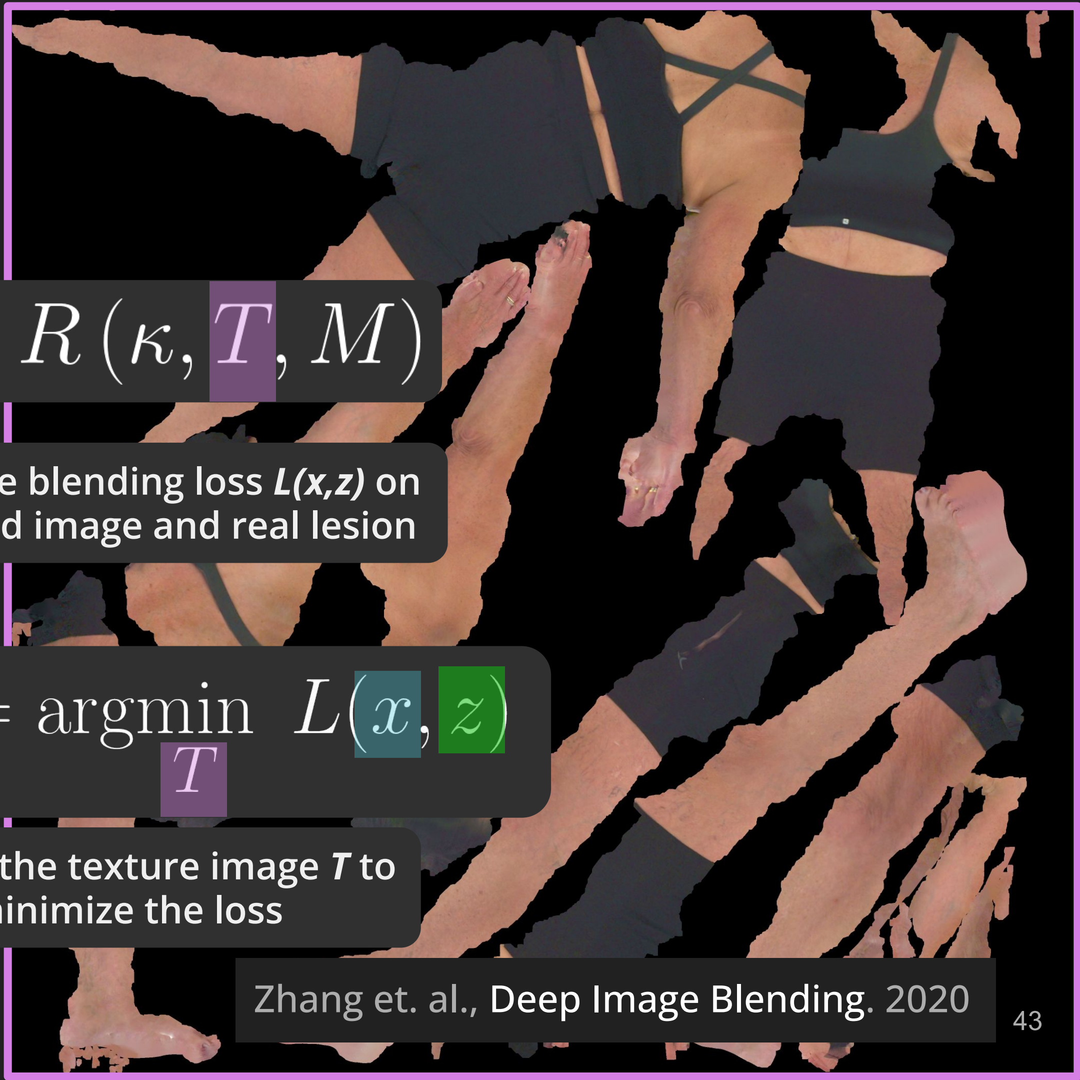
Segmented real lesion

$$x = R(\kappa, T, M)$$

Compute blending loss ***L(x,z)*** on rendered image and real lesion

$$T^* = \underset{T}{\operatorname{argmin}} \; L(x, z)$$

Update the texture image ***T*** to minimize the loss



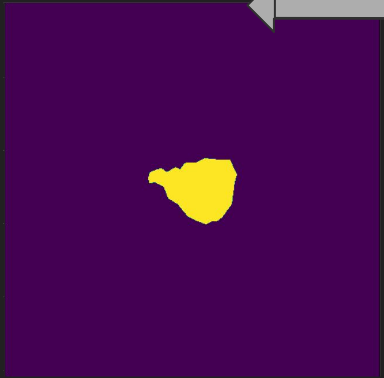
Zhang et. al., Deep Image Blending. 2020

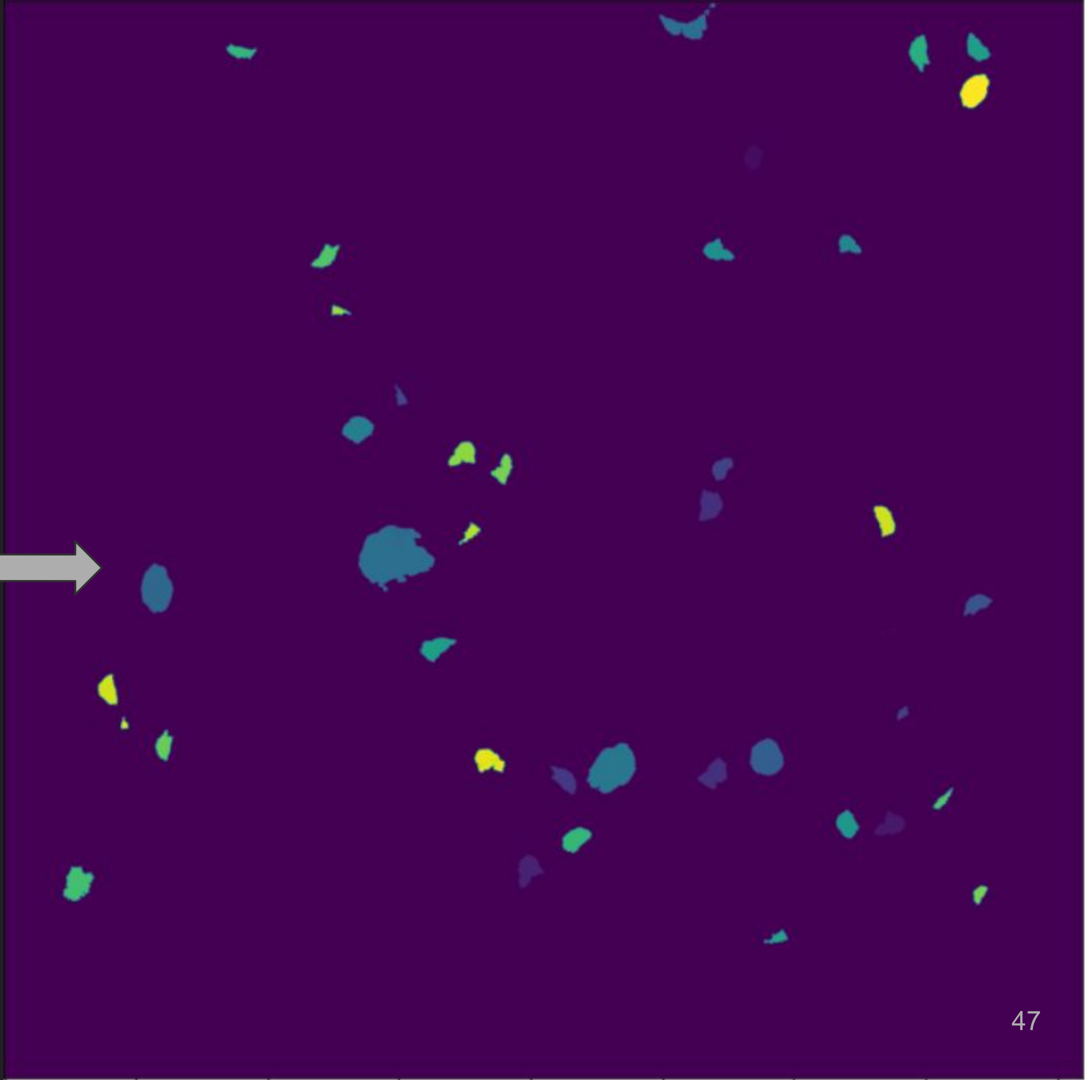
Before Blending Lesions

After Blending Lesions

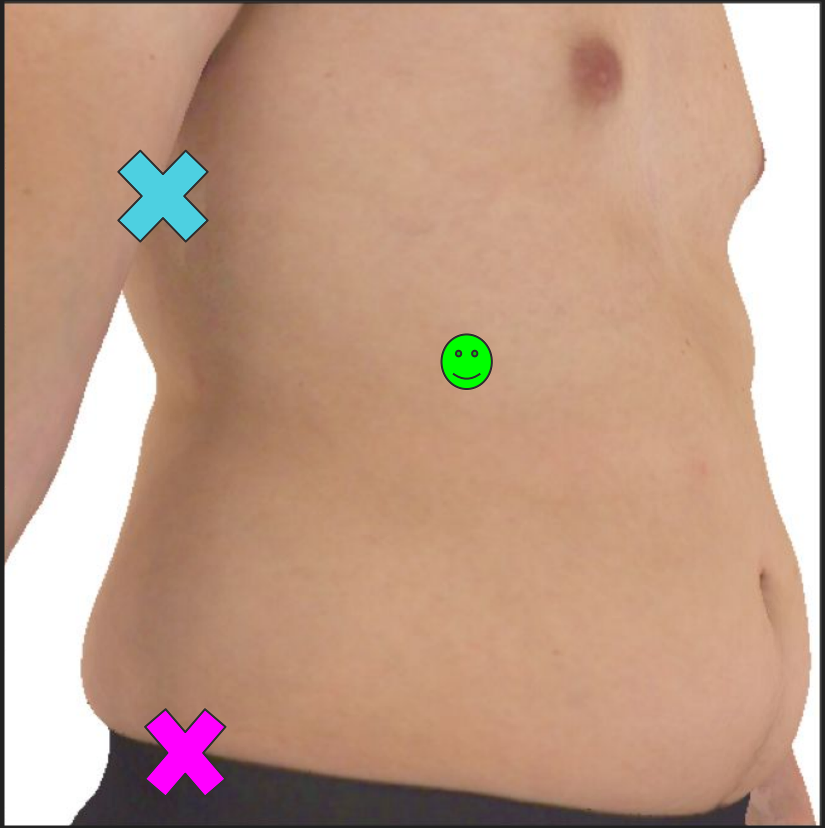
After Blending Lesions

Lesion Segmentations





Placing the Lesion: Depth and Clothing

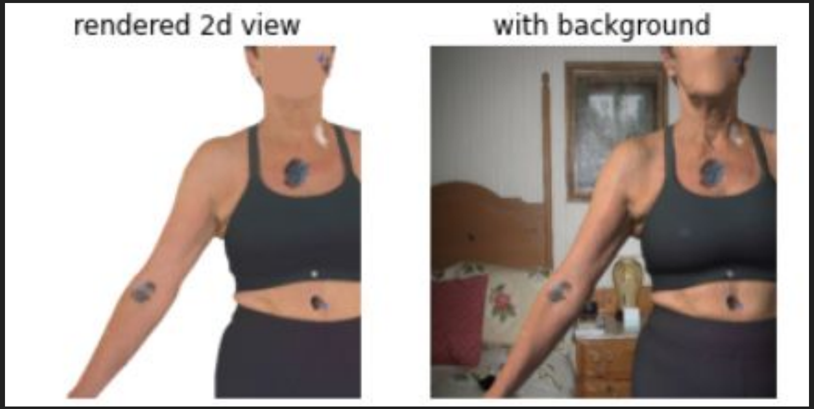


Depth: distance to camera

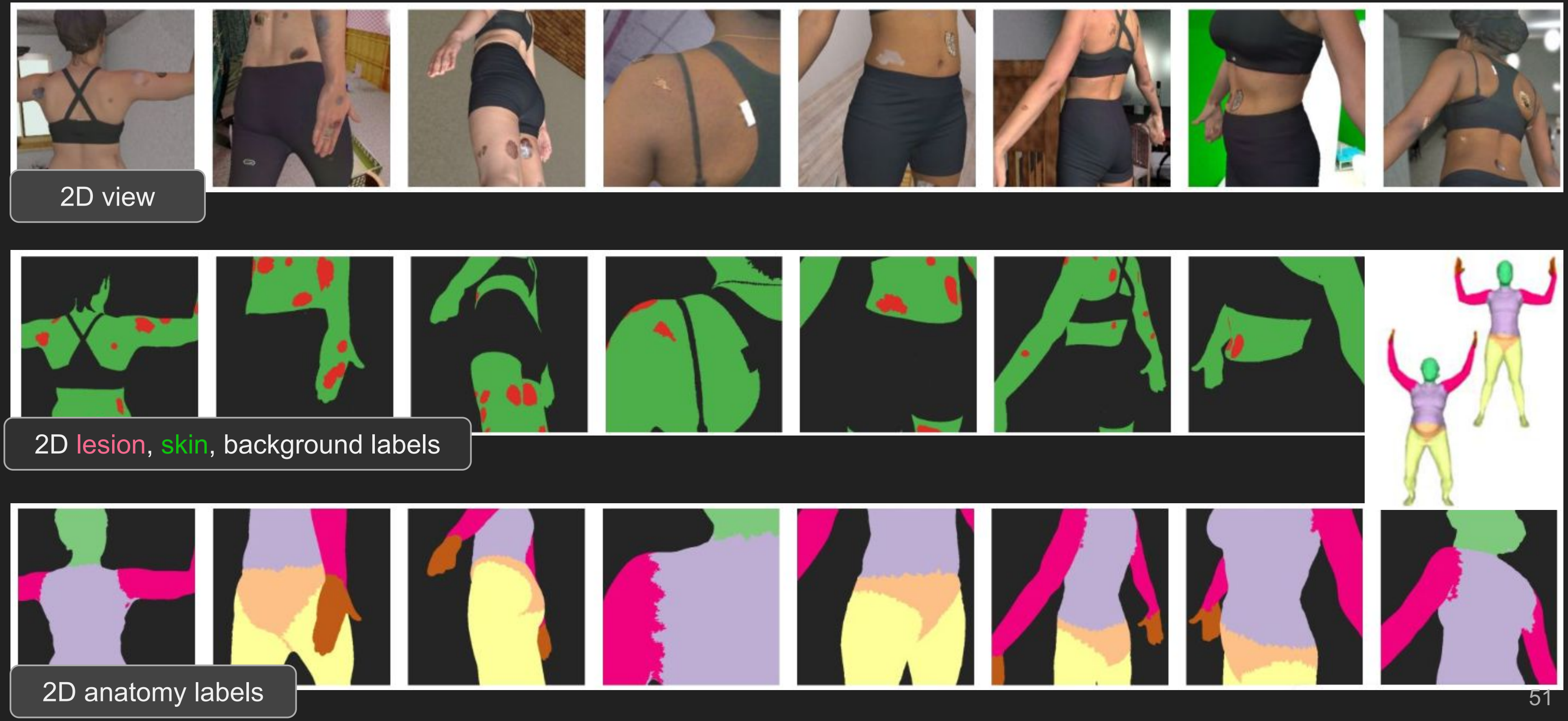
Avoid areas with large depth changes

Segmented Clothing

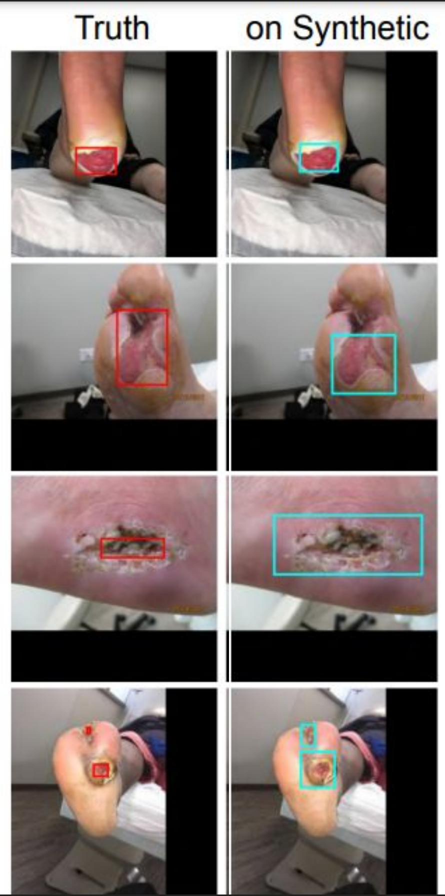
3D Scene Parameters and Backgrounds

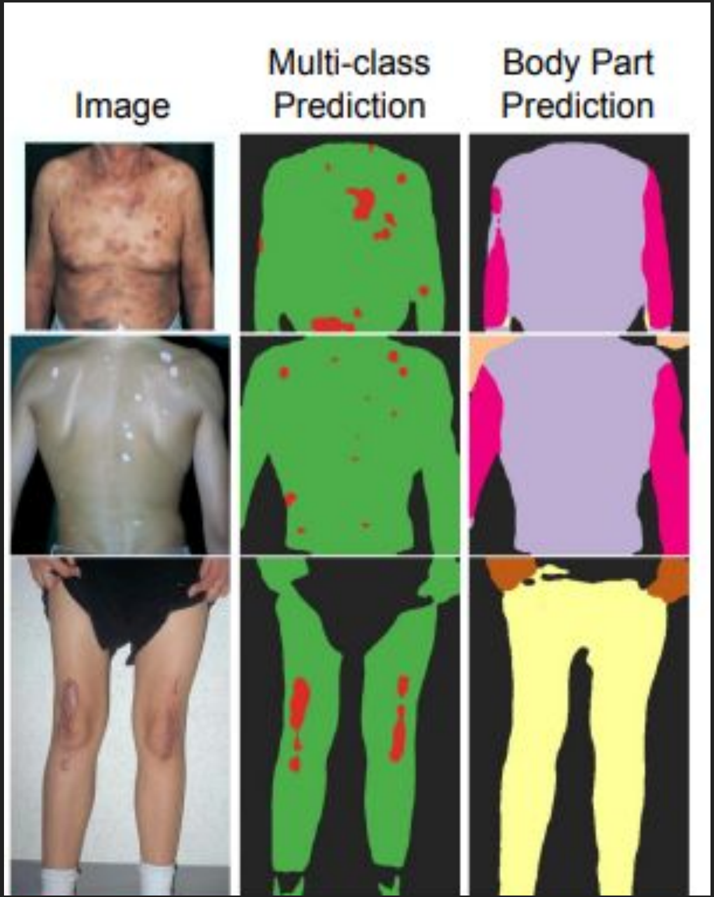


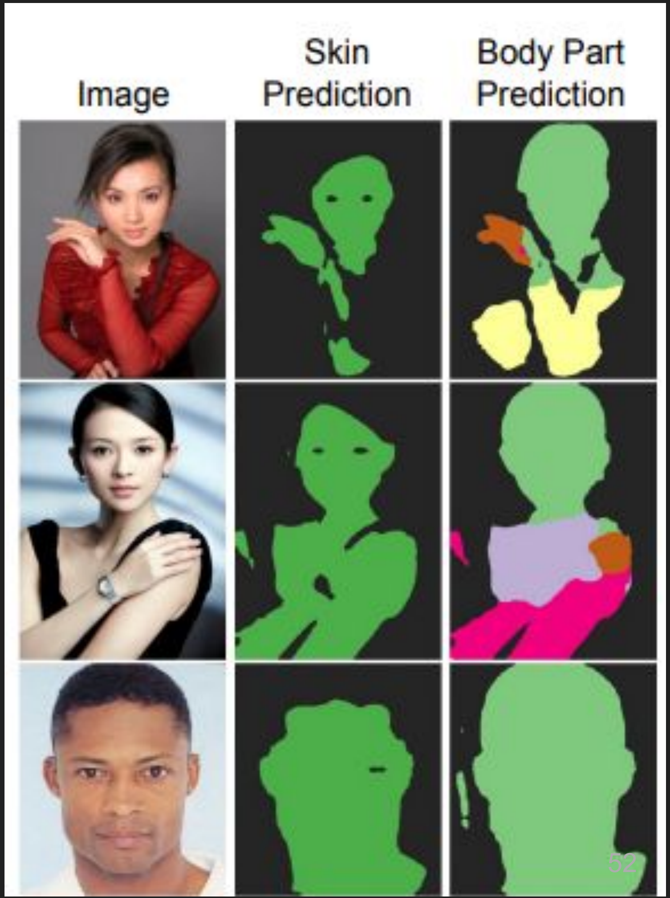
Create 2D labelled datasets from 3D data for ML



Qualitative Results: train on synthetic, test on real







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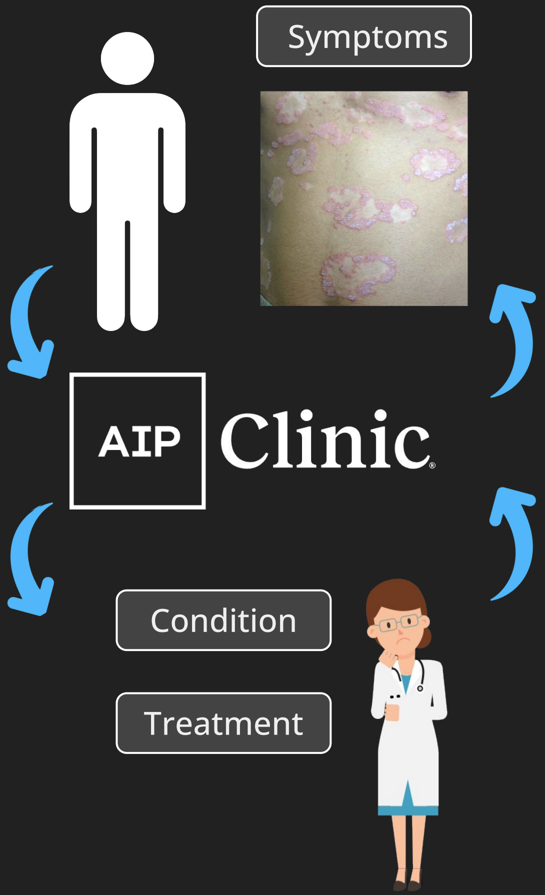
Web-based platform in Hungary, Slovakia, and Spain

User sends a photo and symptoms to our platform, AI processes the case, forward to a human clinician

Human clinician reviews and returns a skin condition and a treatment



Online Regional Application

Free pilot in Hungary with **Semmelweis University**

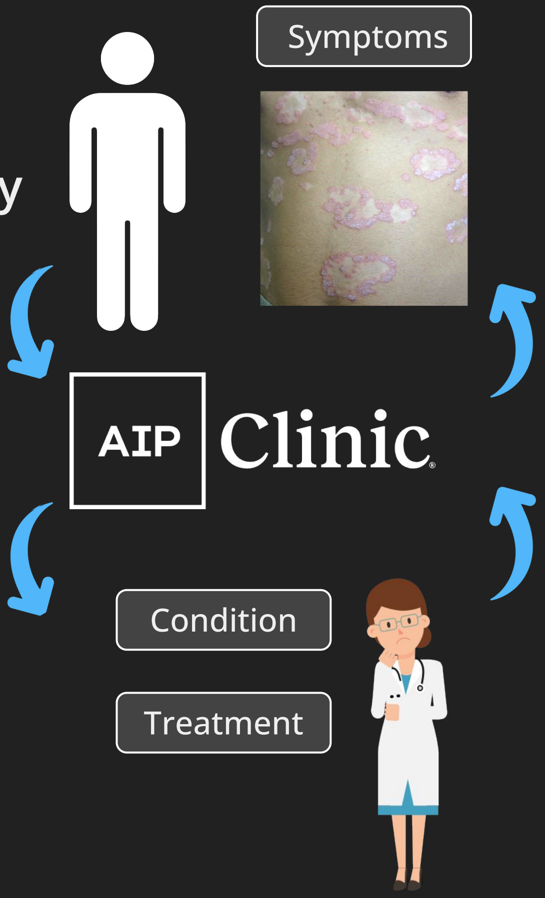
- Large public interest with ~30,000 registered users in ~6 months in 2022

Hungary: Paid service direct to users

Slovakia: Through an insurance company

Spain: Recently opened for direct users

Partner with clinicians in the region



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User Statistics

Age	Hungary
0 - 25	14%
25 - 50	53%
50 - 75	29%
75+	4%

Fitzpatrick	Hungary
I - II	81.9%
III - IV	17.9%
V - VI	0.2%

	Hungary
Female	56%
Male	44%

	Slovakia
Female	64%
Male	36%

30%+ of users aged 50+

Most Fitzpatrick I - II
Some Fitzpatrick III-VI

Majority female users, especially in Slovakia

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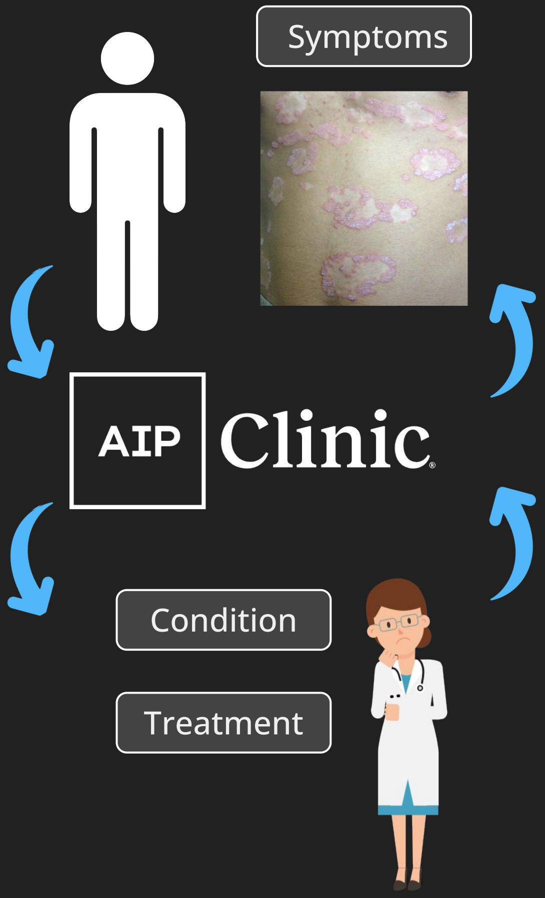
Machine Learning Use

Quality check for low quality images

- Prompt users to retake images immediately
- Limits low quality images that reach clinicians

Suggest skin conditions to the clinician

- Uses image and the symptoms (e.g., itchy)
- Clinicians see a variety of plausible conditions
- Limits clinician effort searching through hundreds of conditions



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Common Conditions & Treatments

Rank	Hungary (Free pilot)	Hungary (Paid Service)
1	Common Mole	Contact Dermatitis
2	Seborrheic Keratosis	Seborrheic Keratosis
3	Atypical Mole	Atypical Mole
4	Contact Dermatitis	Dyshidrotic Eczema
5	Dermal Nevus	Ringworm

Treatment	Hungary (Free)	Hungary (Paid)
Clinic visit	61%	30%
Prescription	22%	62%
Over-the-counter	15%	7%
None	2%	1%

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Common Conditions & Treatments

Rank	Hungary (Free pilot)	Hungary (Paid Service)
1	Common Mole	Contact Dermatitis
2	Seborrheic Keratosis	Seborrheic Keratosis
3	Atypical Mole	Atypical Mole
4	Contact Dermatitis	Dyshidrotic Eczema
5	Dermal Nevus	Ringworm

Benign moles occurred frequently in the **free pilot**, but less frequently in the **paid service**

Treatment	Hungary (Free)	Hungary (Paid)
Clinic visit	61%	30%
Prescription	22%	62%
Over-the-counter	15%	7%
None	2%	1%

Pilot: 60% referred to in-person clinic
(early hesitation of clinicians + many moles)

Paid: 30% referred to in-person clinic
(fewer moles)

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Integrating Regional Prescriptions

Prescriptions appropriate to the region

- Regional prescription database

Ensure patients can access and fulfill the prescriptions

- Integrate with regional e-health systems
- Allow patients to pick up prescriptions from a local pharmacy

Treatment	Hungary (Free)	Hungary (Paid)
Clinic visit	61%	30%
Prescription	22%	62%
Over-the-counter	15%	7%
None	2%	1%

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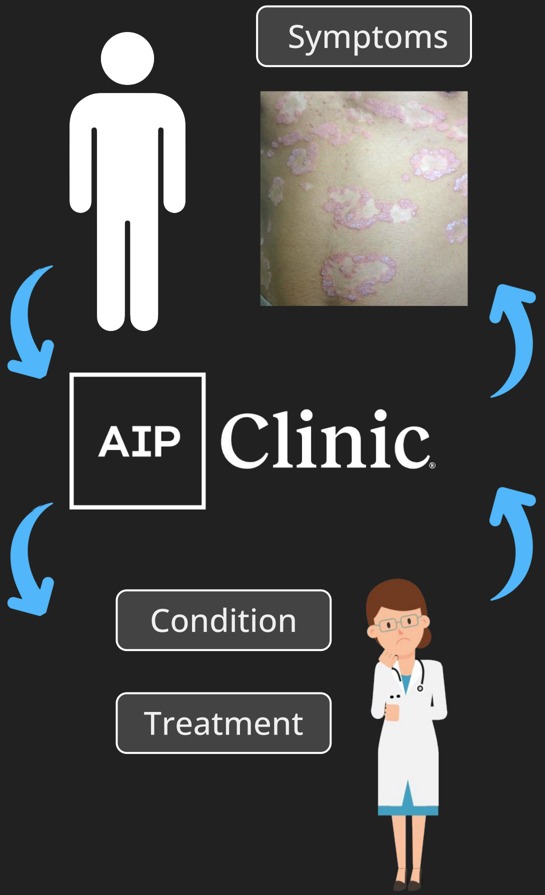
Closing Thoughts

Diagnosis is one step

- Patients need **treatments**
- ML systems to predict treatments?
- 1 diagnosis can have many treatments
- Treatments may offer insights into severity

ML tools to support clinicians and users

- Humans drive the decision steps



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Summary

2D dermatology images

Detecting and tracking moles on 3D body scans

Blending real 2D images on 3D meshes and creating synthetic dataset

Dermatology application used in Europe

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End