Differentiable Physics for Learning & Control

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Motivation: *Networked XR ~ Metaverse*

Among most disruptive technologies for next decades

- According to E&T, Forbes, Goldman Sachs, Holmes Report, etc.
- Major tech companies are investing in XR related technologies (display, tracking, headphone, etc)
- Expected to generate 100's billions
- *Applications are limitless!!!*

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Some Important Problems

- Low-Latency, Large-Area Tracking
- Immersive Display
- 3D User Interfaces
- Interactive 3D Graphics
- Realistic Modeling & Simulation
- Intuitive Haptic (Touch-Enabled) Feedback
- Real-time Sound Rendering
- ***Constructing the Metaverse***

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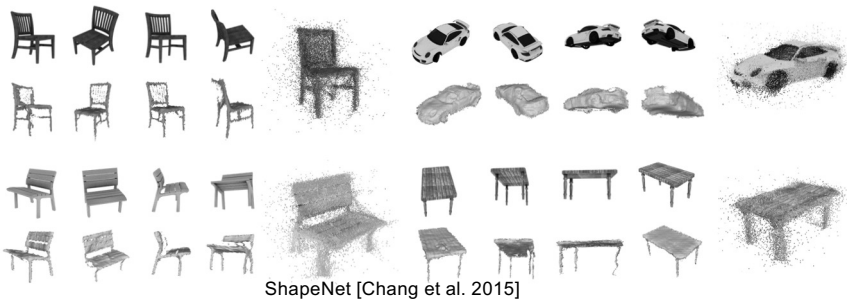
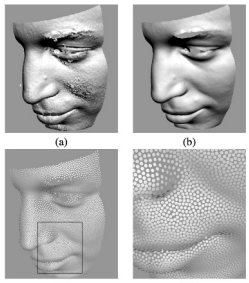
Prior Work on Geometry Reconstruction



ShapeNet [Chang et al. 2015]



[Lipman et al. ACM TOG 2007]

Marching Cube [Lorensen; SIGGRAPH 1987]

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Prior Work on Scene Reconstruction

Office of the Future [Raskar et al. SIGGRAPH 1998]

ScanNet [Dai et al. CVPR 2017]

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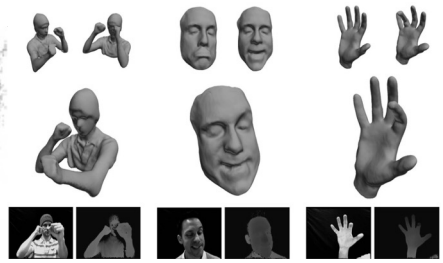
Priors on Image/Video Reconstruction

[Pollefeys et al; IJCV 1998]

[Frahm et al; ECCV 2010]



[Zollhofer et al; TOG 2014]

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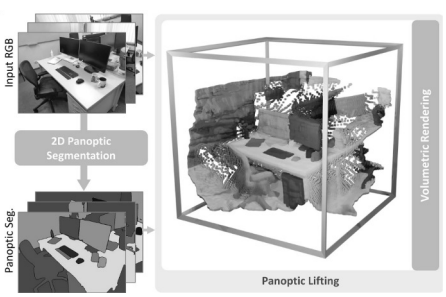
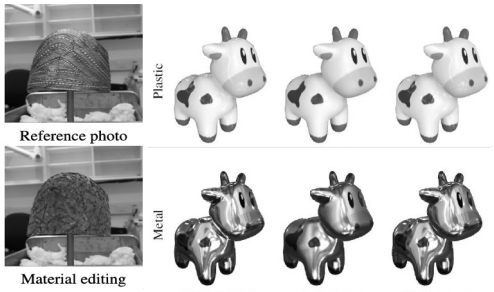
Recent on Photorealistic Reconstruction

NeRF [Mildenhall et al; ECCV 2020]



NeRFStudio [Siddiqui et al; 2022]



NVDiffrec [Munkberg et al; CVPR 2022]

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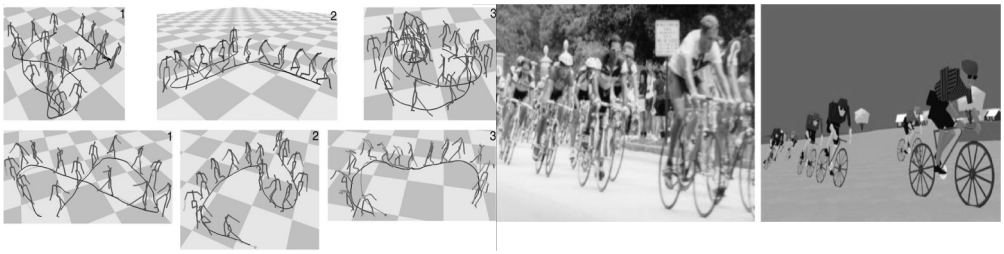
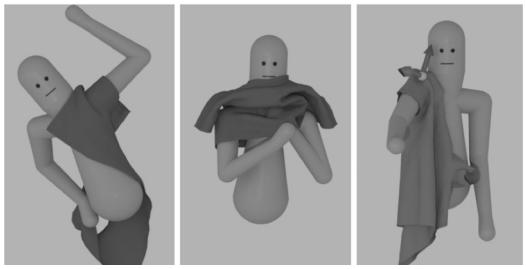
Priors on Motion Control & Reconstruct



[Kovar et al; SIGGRAPH 2002]

[Hodgins et al; SIGGRAPH 1995]

[Ren et al; ACM TOG 2005]



[Clegg et al; ACM TOG 2018]

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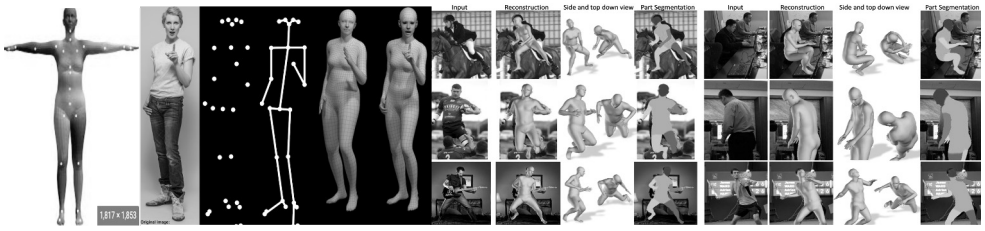
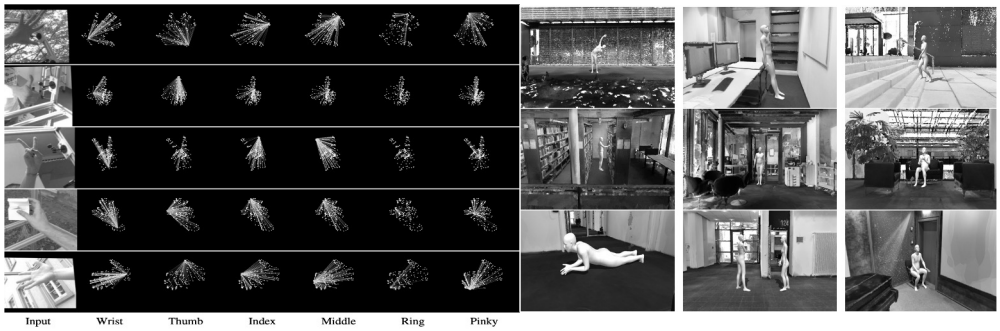
Creating Digital Avatars



SMPL **[Loper et al; TOG 2015]** **HMR [Kanazawa et al; CVPR 2018]**



[Lin et al; CVPR 2021] **[Guzov et al; CVPR 2021]**

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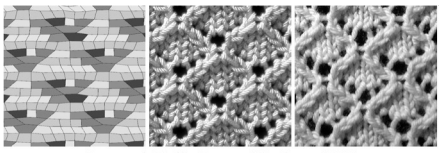
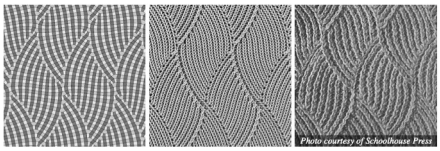
Reconstructing Cloth, Fabrics, and Garments

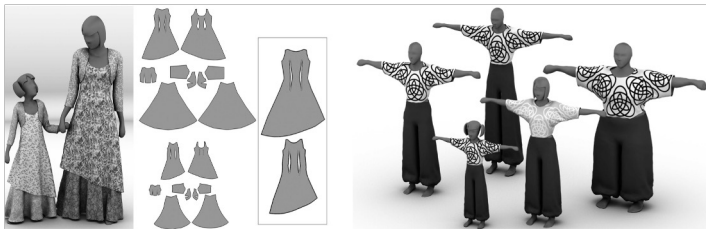
[Narayanan et al; SIGGRAPH 2019]



Openwork Trellis Pattern [Matthews 1984]



Flame Ribbing Pattern [Walker 2001]



[Brouet et al; SIGGRAPH 2012]

[Yuksel et al; SIGGRAPH 2012]

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Data Capturing Physical Worlds

- 2D Images (photos, drawings/paintings)
- 3D Geometry & Models
- N-D Motion Capture
- Audio
- Video
- Medical Information
  - CT, Ultrasound, MRI, Patient Records
- Sensor Data
  - Traffic/environmental monitoring, measurements, etc.
- Other (documents, social media, web, etc)

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Challenges

- Diversity of data representations/formats
  - 2D vs. 3D vs. n-dimensional
  - Text, numbers, images, audio, video, abstract
  - Geometry, physics, appearance, behaviors
- Volumes of data
- Noises, uncertainty, incompleteness

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Smart Cities

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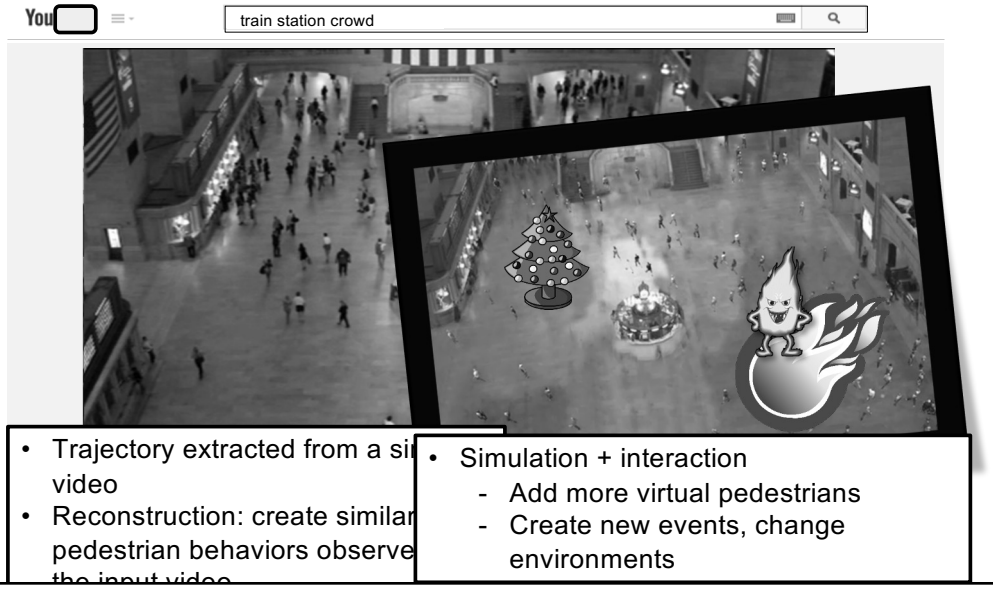
Data-Driven Crowd Simulation: Ultimate Goals



- Trajectory extracted from a si
  video
- Reconstruction: create similar
  pedestrian behaviors observe
  the input video

- Simulation + interaction
  - Add more virtual pedestrians
  - Create new events, change environments

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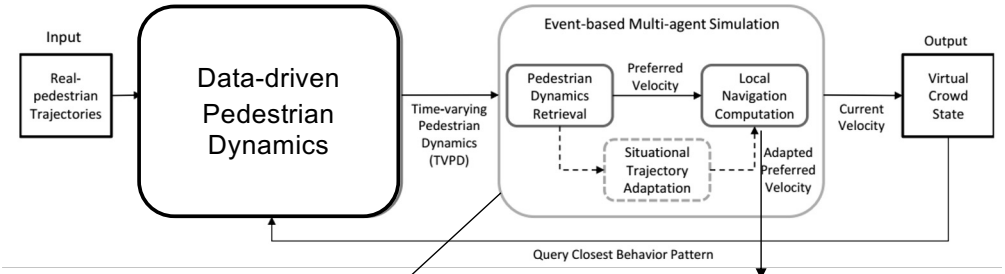
Crowd Behavior Adaptation



- Density-dependent behavior [Best et al. 14]
- Situational behavior adaptation [Kim et al. 12]
- Etc…

- Social-forces model
- Velocity-based method
- Etc…

Supported by ARO

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Data-Driven Crowd Simulation: Example Demo

[Kim et al. IEEE VR & TVCG]

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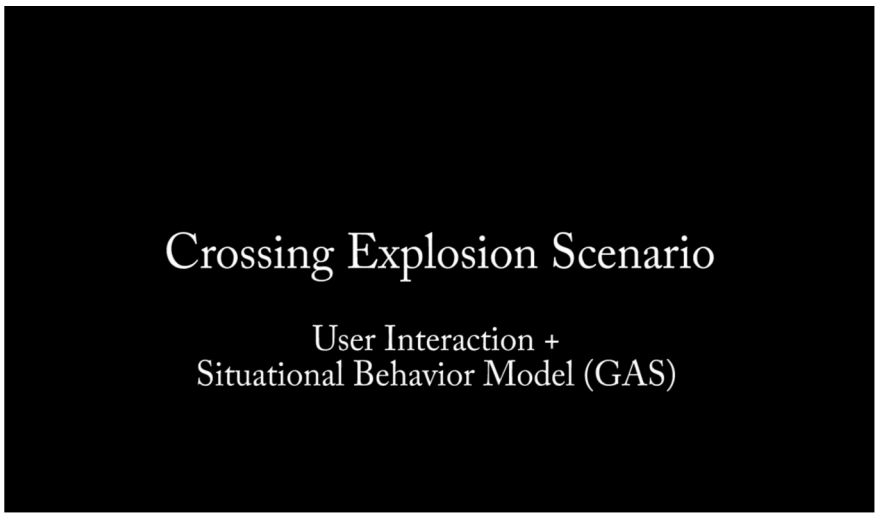
Data-Driven Crowd Simulation: Example Demo



[Kim et al. IEEE VR & TVCG]

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Virtualized Traffic: Motivation

- To reconstruct virtualized traffic using temporal-spatial (road) sensor data
- Traffic data would help route planning & add realism
- Reconstruction should be on-line — stream computation as data becomes available

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Virtualized Traffic for Autonomous Driving

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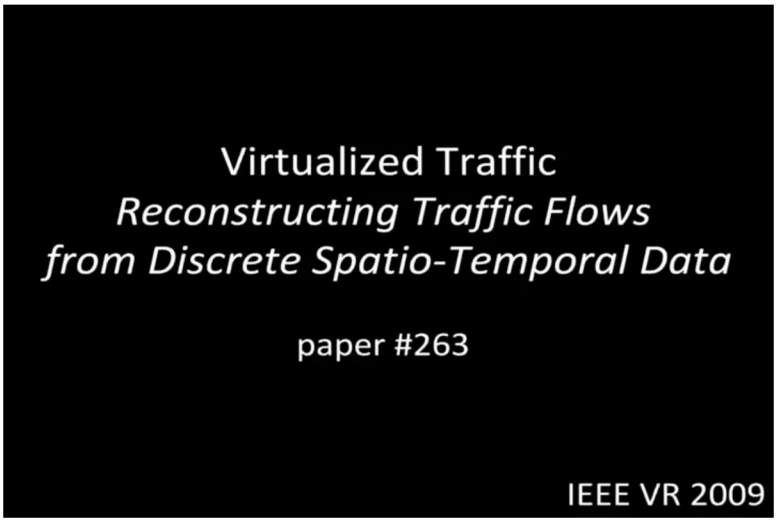
Virtualized Traffic: System Demonstration



[van den Berg et al. IEEE VR; TVCG]

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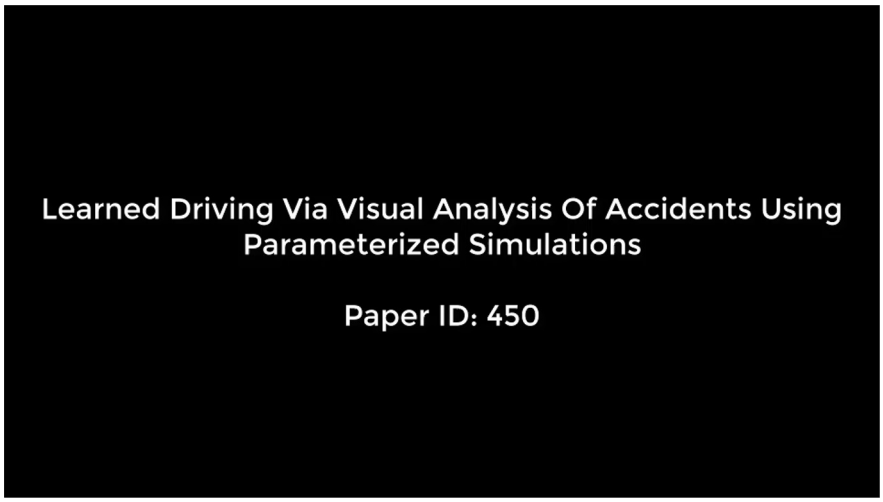
Learning How NOT To Drive



[Li et al. IEEE ICRA 2019]

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Learning from Simulated Accidents

[Akhauri et al. IEEE IROS 2020]

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Ongoing Research Issues

- New techniques for crowd and traffic computations
  - Measurement-driven Local Navigation
  - Reality-based Cognitive Modeling
  - Simulating Abnormalities & Unexpected
  - Authoring, Directing & Interacting
  - Behavior Capturing & Tracking
  - ***Training Autonomous Vehicles***
- Mapping to commodity hardware
  - data parallelism, thread-level parallelism, etc.
  - Reconstruction in the Cloud
- Metrics & approaches for evaluation & validation

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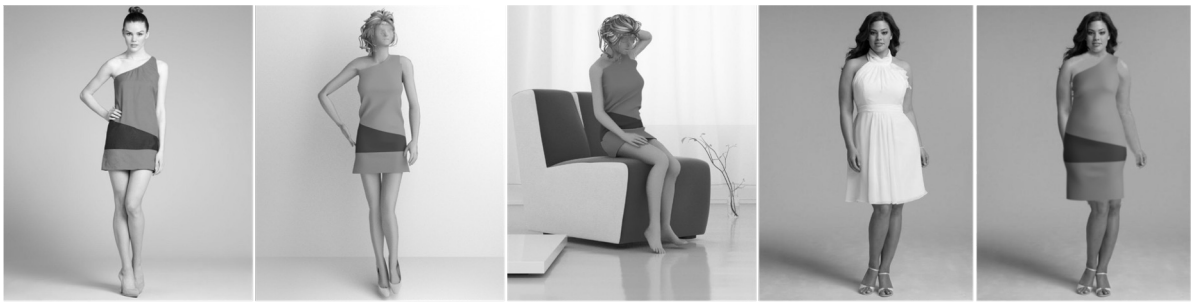
Virtual Try-On

Collaborators: Tamara Berg, Jan Frahm and Dinesh Manocha
Students: Junbang Liang, Shan Yang, Yu Shen, Tanya Amert

University of North Carolina at Chapel Hill
University of Maryland at College Park

Industrial Partner: Amazon



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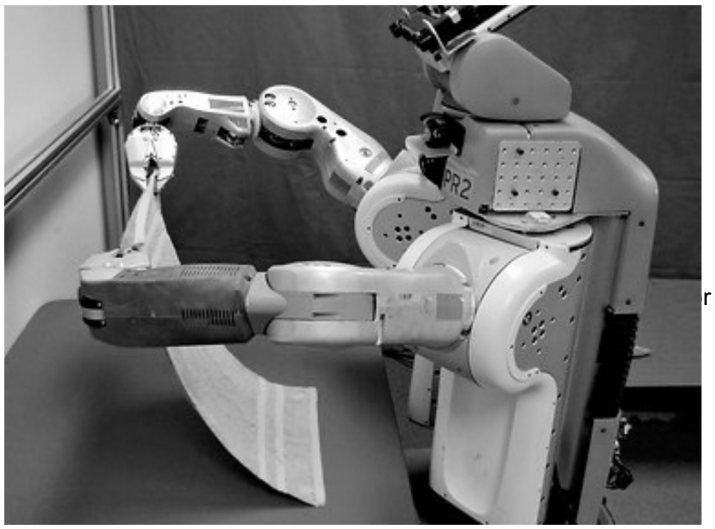
Motivation: Household Robots



Robot Folding Cloth (UC Berkeley)

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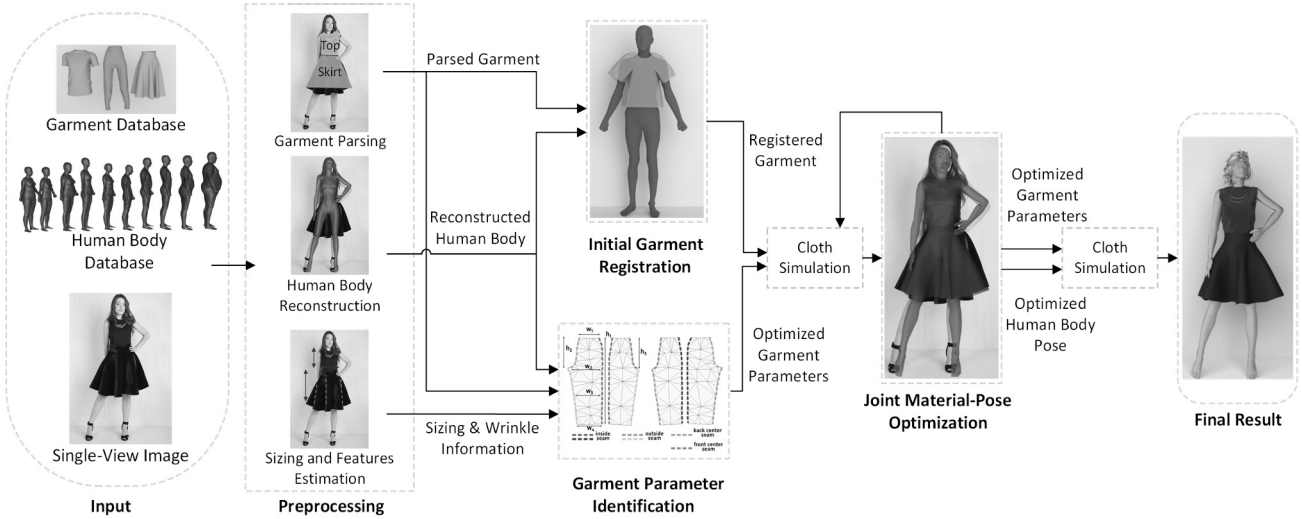
Single-view Image Garment Recovery
System Overview



[Yang et al.; ACM TOG / SIGGRAPH 2018]

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Single-view Image Garment Recovery: Results

[Yang et al.; ACM TOG / SIGGRAPH 2018]

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Single-view Image Garment Recovery: *Retargeting*

[Yang et al.; ACM TOG / SIGGRAPH 2018]

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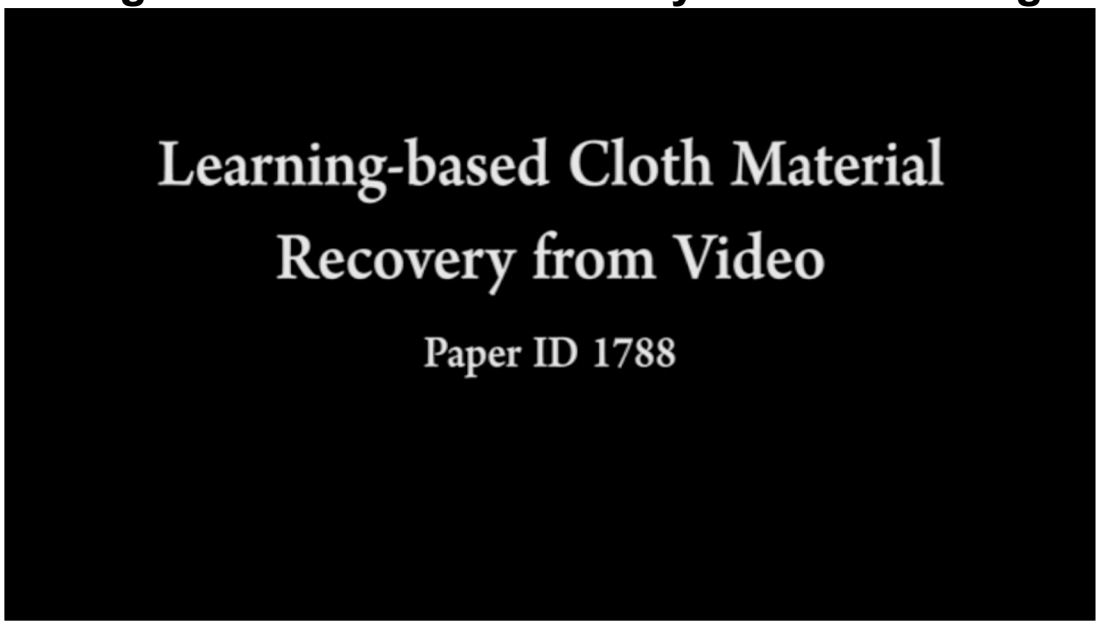
Learning-based Material Recovery: Fabric Cloning



[Yang et al.; ICCV 2017]

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Shape-Aware Human Pose and Shape Reconstruction *Using Multi-View Images*

- **Shape-aware body reconstruction using parametric model**
  - *Articulated output with shape supervision*
- **Scalable multi-view learning framework**
  - *Can accept any number of RGB images at inference time*
- **A large synthetic dataset with ground-truth parameters**
  - *Wide-clothed human bodies that enriches the data variation*

[Liang & Lin; ICCV 2019]

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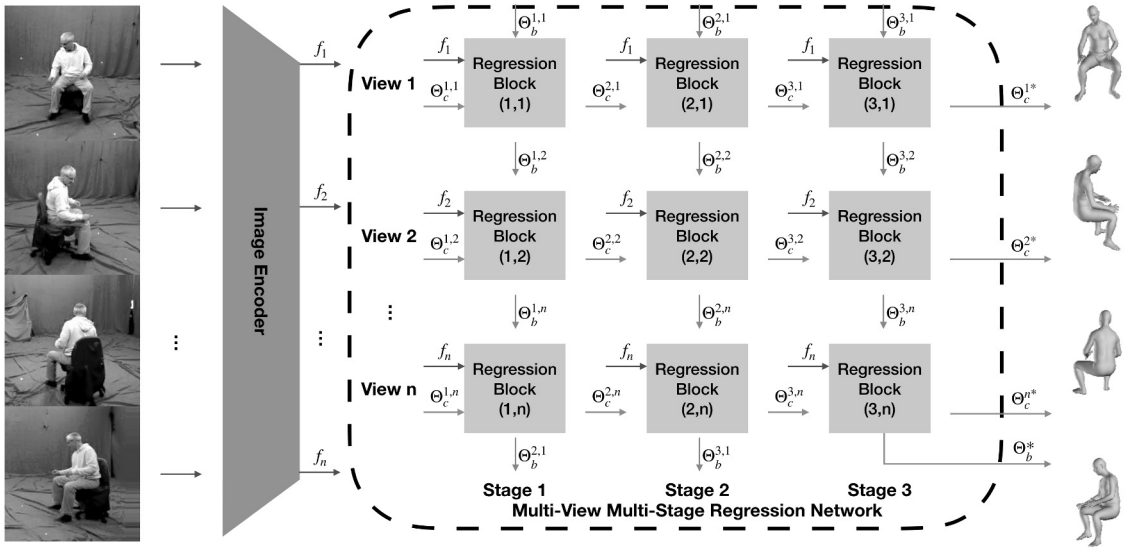
Network Structure



[Liang & Lin; ICCV 2019]

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Results & Comparison

Ours offers better shape recovery in non-standard human shape input and better pose recovery with multi-view images.

[Liang & Lin; ICCV 2019]

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Future Research Issues

- Interactive, high-fidelity garment Simulation
- Automatic parameter selection based on examples (videos, images, drawings, etc)
- Robustness issue in body reconstruction
- *Differentiable rendering, geometry, and simulation* for design pattern recovery
- Design of customized apparel
- Smart fabrics & 3D printing

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Realistic Garment Draping Prediction for Virtual Try-On using Learning Model

Merch by Amazon "See It On Me"

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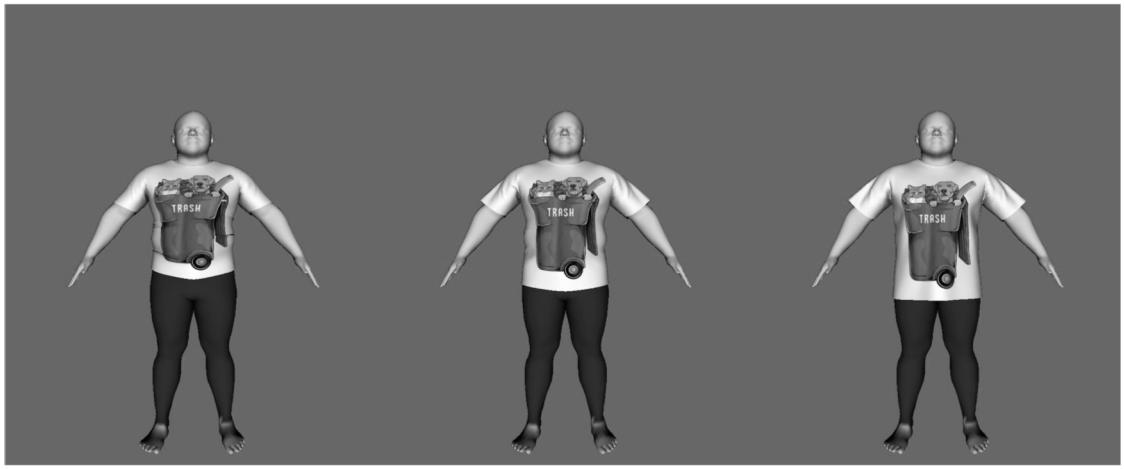
Visualization of different sizes

Visible differences in T-shirt length and fit



Small Medium Large

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Virtual Try-On

Semi-Supervised Learning of
Physics-Enforced Garment Prediction

Paper 1225

[Liang et al; Accepted to CVPR 2022]

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