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The University of Dublin

V-SENSE

Volumetric Video

Professor Aljosa Smolic

SFI Research Professor of Creative Technologies

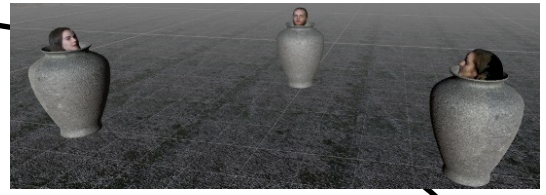
Trinity College Dublin
The University of Dublin

V-SENSE

Science Foundation Ireland sfi For what's next

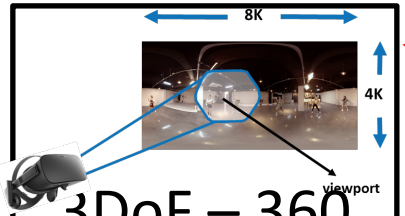
- **Extending Visual Sensation through Image-Based Visual Computing**
- **Visual computing at the intersection of**
  - Computer graphics
  - Computer vision
  - Media technology
- **Algorithms on pixels from capture to display**
- **Immersive visualization, VR, AR**

V-SENSE Research Areas

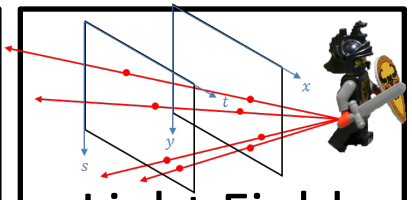


Creative
Experiments and Demonstrations

Visual Effects
& Animation



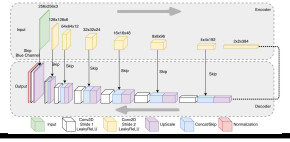
3DoF – 360
VR Video



Light Field
Imaging

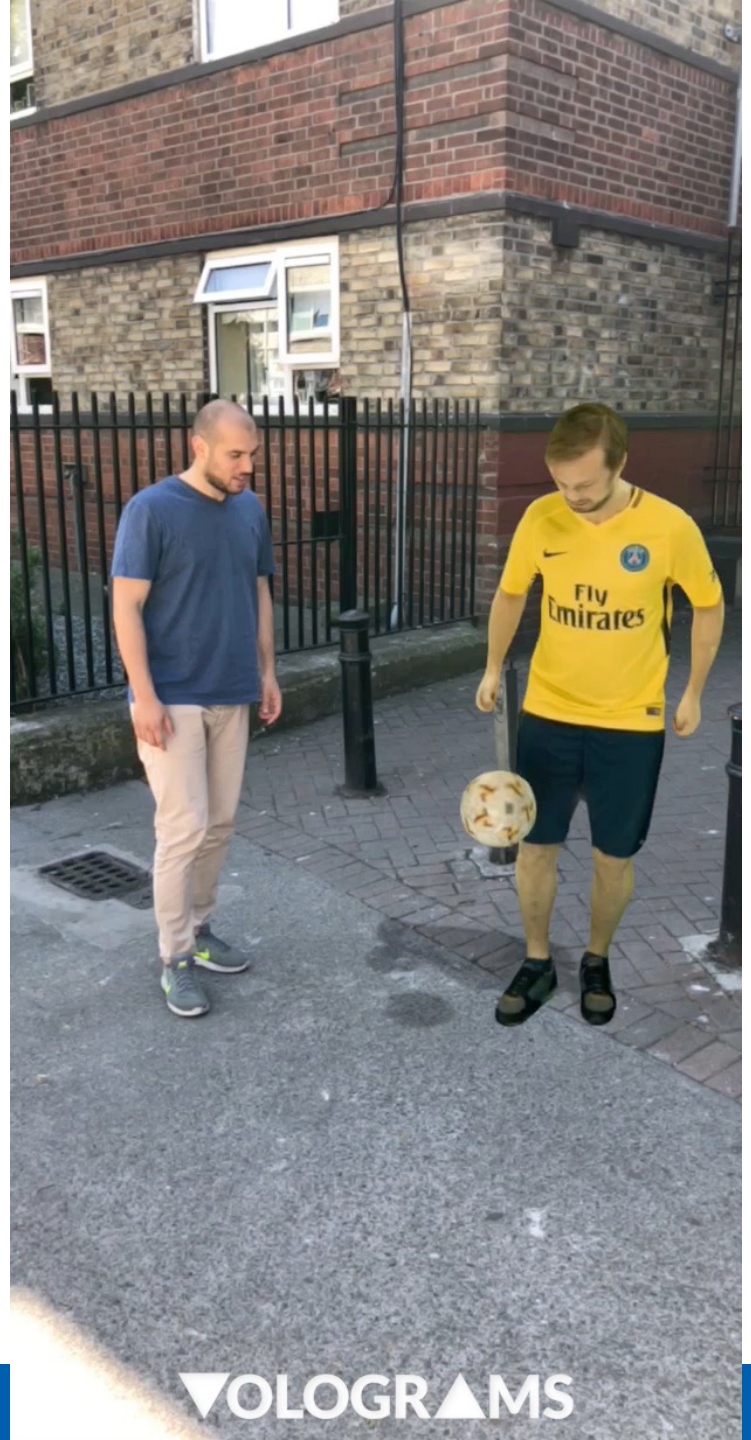
6DoF –
AR/VR &
Free
Viewpoint
Video

Deep Learning for Visual Computing



Coding/Streaming

Quality, Visual Attention



VOLOGRAMS

Outline

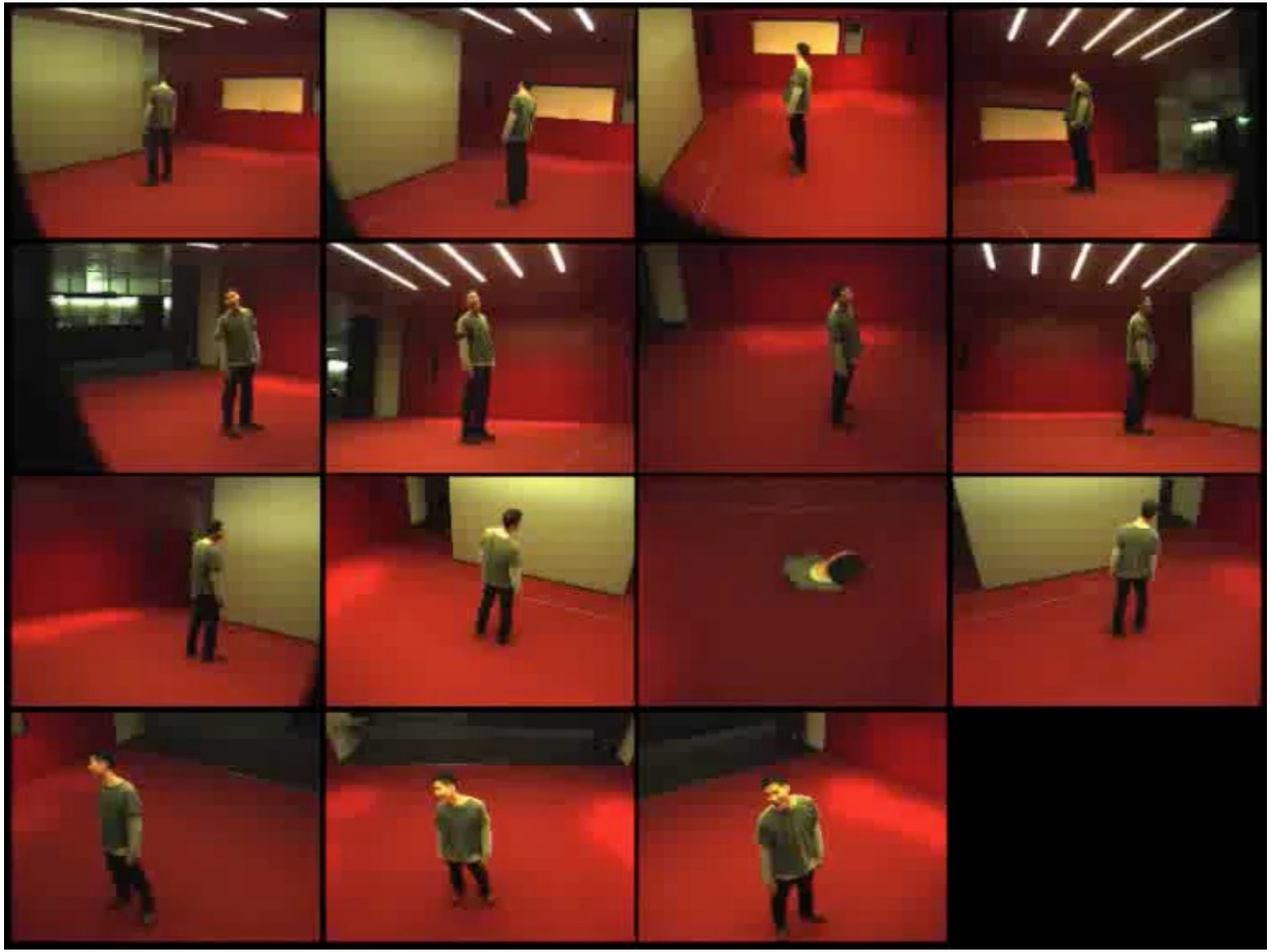
- **Introduction**
- **“Traditional” VV Content Creation**
- **3D Deep Learning for VV Content Creation**
- **Creative Experiments**
- **Conclusion**

Volumetric Video

- **Same functionality as CG objects**
  - free navigation, can be viewed from any viewpoint/direction
  - Integration into complete scenes (virtual/augmented/real)

- **But:** depict appearance, motion, deformation of **real world objects**

Multi-view 2D Video



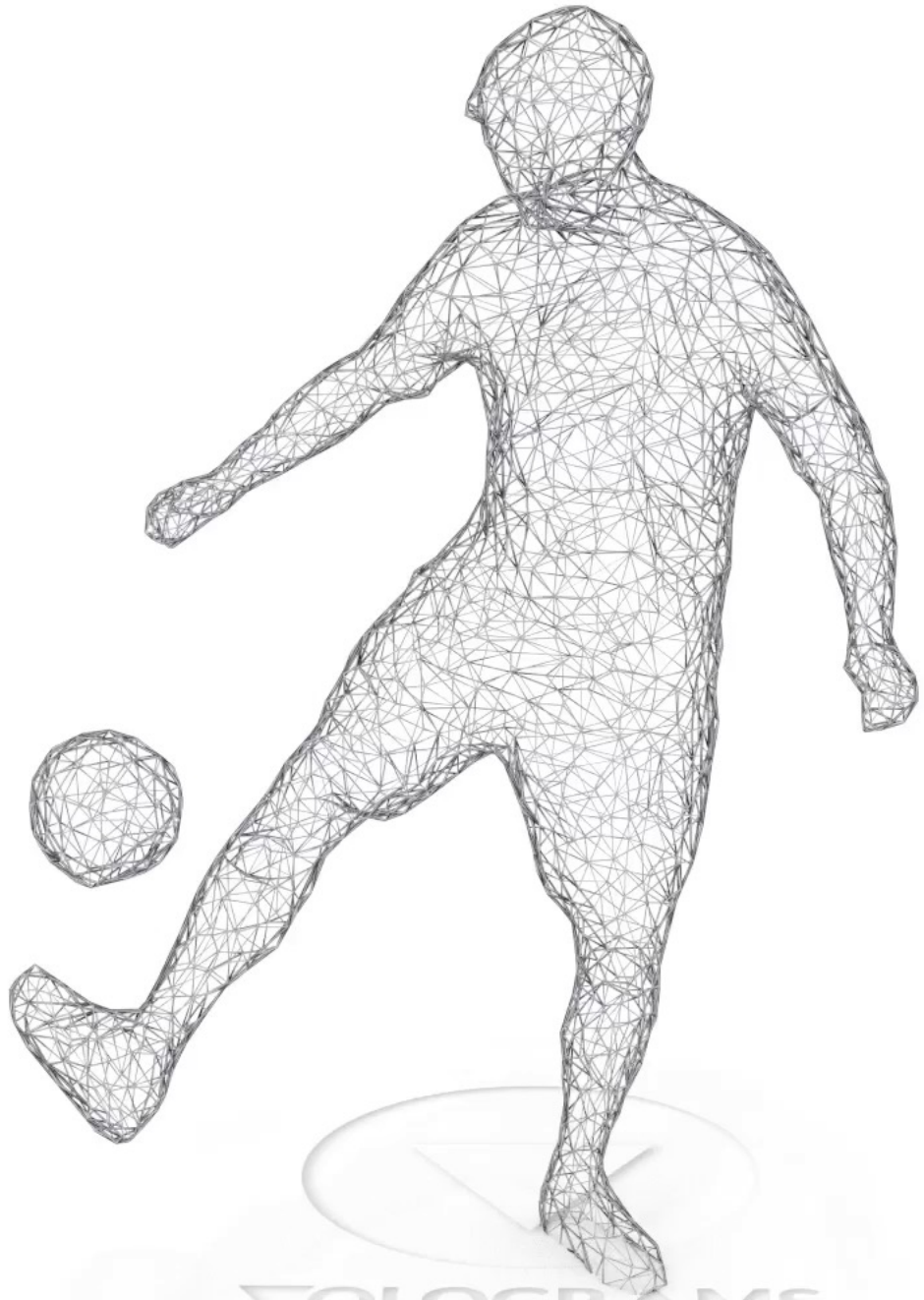
Volumetric Video

3D reconstruction of real-world scenes and objects

Interactive viewpoint selection

Mixing real and virtual elements

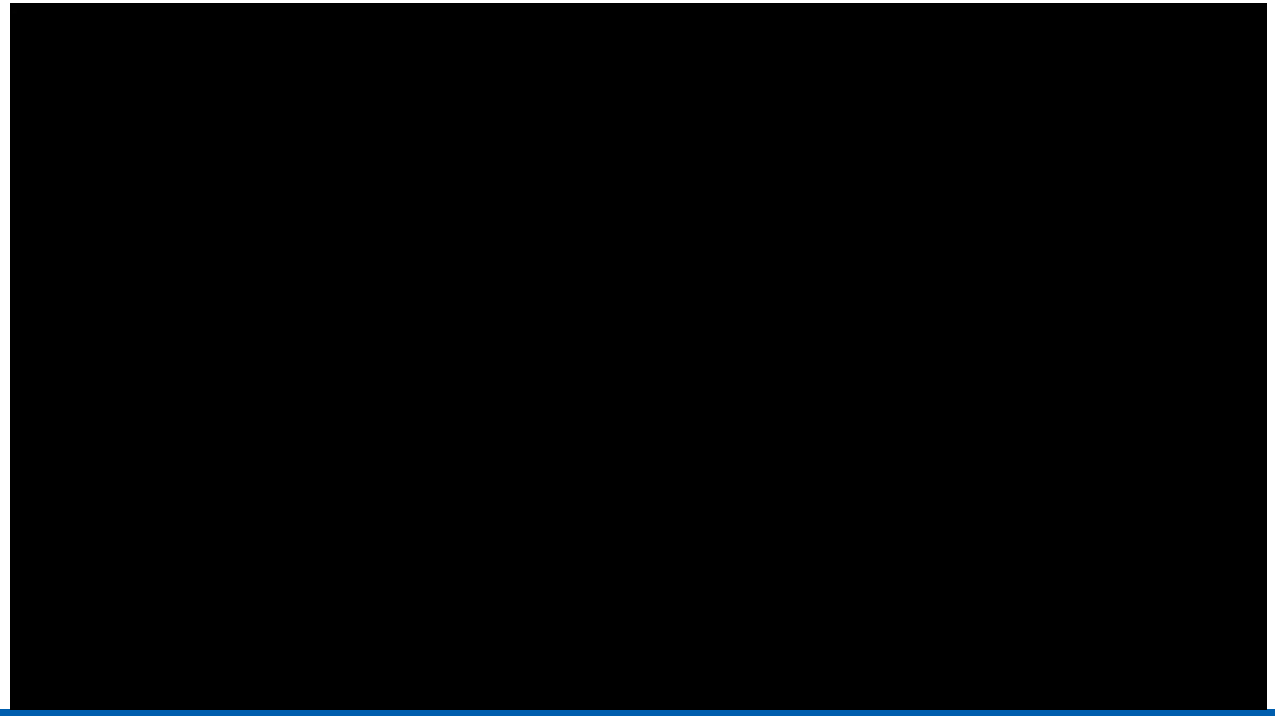
Free viewpoint video extraction, representation, coding, and re
A Smolic, K Mueller, P Merkle, T Rein, M Kautzner, P Eisert, T Wiegand
ICIP'04. 2004 International Conference on 5, 3287-3290



eXtended Reality (XR) with VV on HMDs

Augmented Reality

Virtual Reality



Volumetric Video for Communication and Telepresence

Telepresence: Microsoft Holoportation


ness +
nology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Technology
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V-SENSE

VV Content Creation

Professor Aljosa Smolic

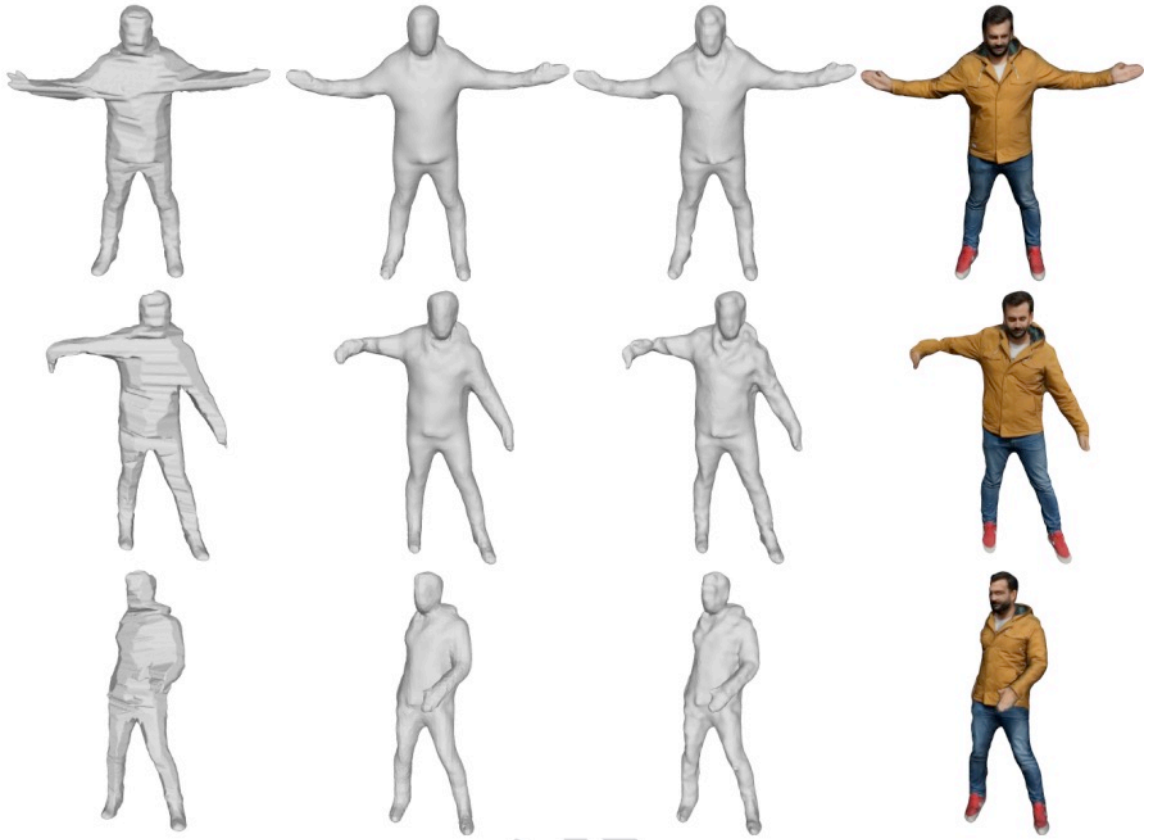
SFI Research Professor of Creative Technologies

VV for VR/AR Content Creation

http://authors.elsevier.com/sd/article/S1047320318300683

R. Pagés, K. Amplianitis, D. Monaghan, J. Ondřej, A. Smolić,
Affordable Content Creation for Free-Viewpoint Video and VR/AR Applications,
J. Vis. Commun. Image R. (2018),
doi: https://doi.org/10.1016/j.jvcir.2018.03.012

2019 JVCI Best Paper Award



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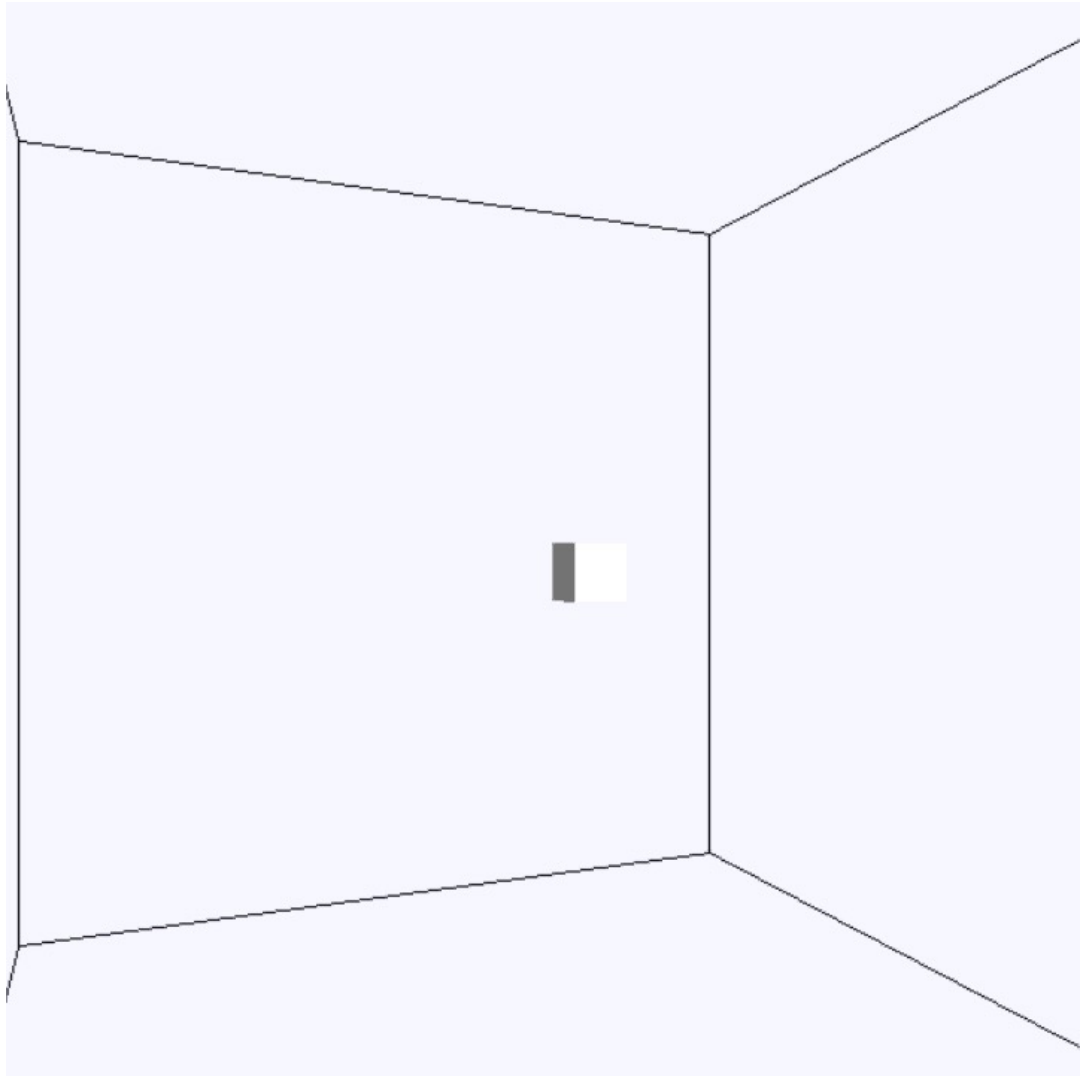
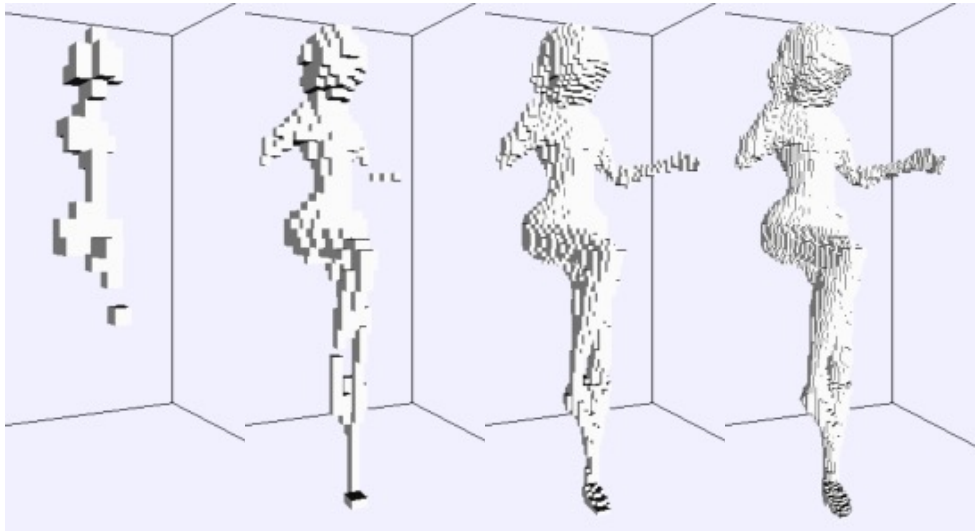
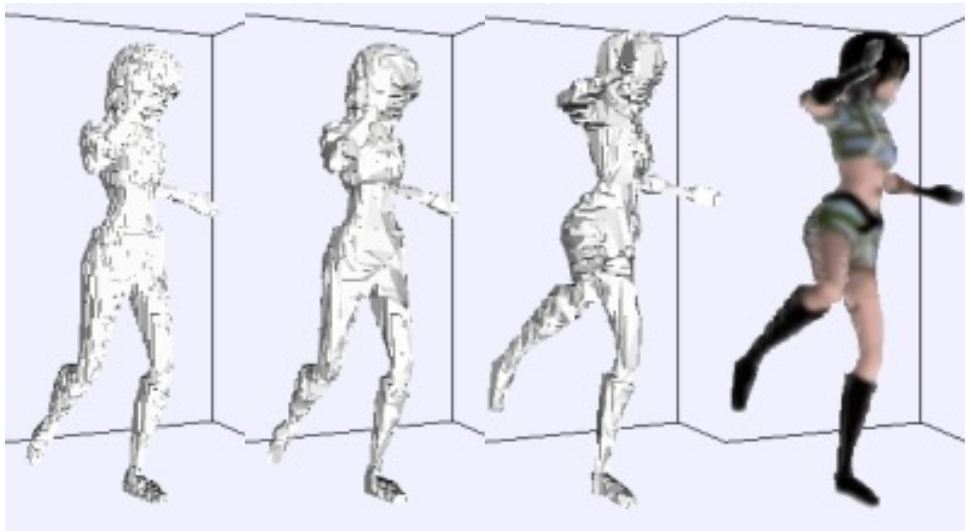
Volumetric 3D Reconstruction



Volumetric 3D Reconstruction

Hierarchical voxel modelling, wire frame transformation and texturing





VV by Shape from Silhouette (SfS)

Shape-from-Silhouette-Approach

a) Hierarchical Voxel Modeling

b) Marching-Cubes-Approach

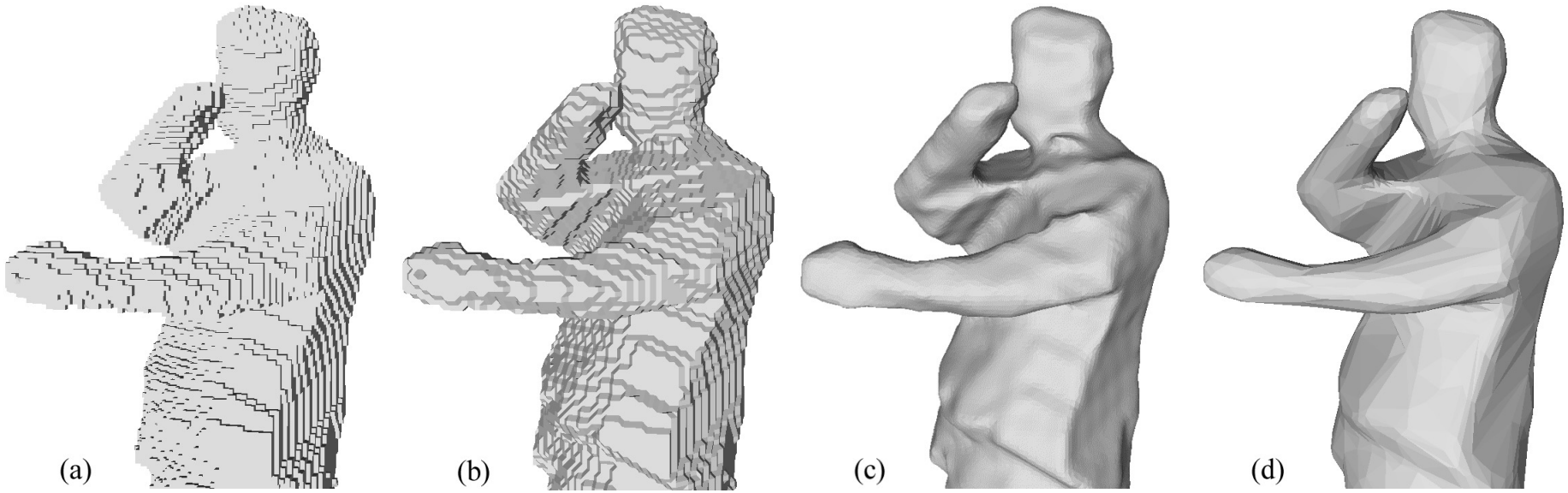
c) Surface Smoothing

d) Mesh Reduction

T. Lewiner *et al.*: Efficient Implementation of Marching Cubes Cases with Topological Guarantee", Journal of Graphics Tools, Vol. 8, pp. 1-15, 2003.

G. Taubin: Curve and Surface Smoothing Without Shrinkage, Proc. IEEE International Conference on Computer Vision (ICCV 95), 1995.

H. Hoppe, Efficient Implementation of Progressive Meshes, Computers & Graphics, Vol. 22, No. 2, pp. 27-36, 1998 / Tool in DirectX



VV by Structure from Motion (SfM)

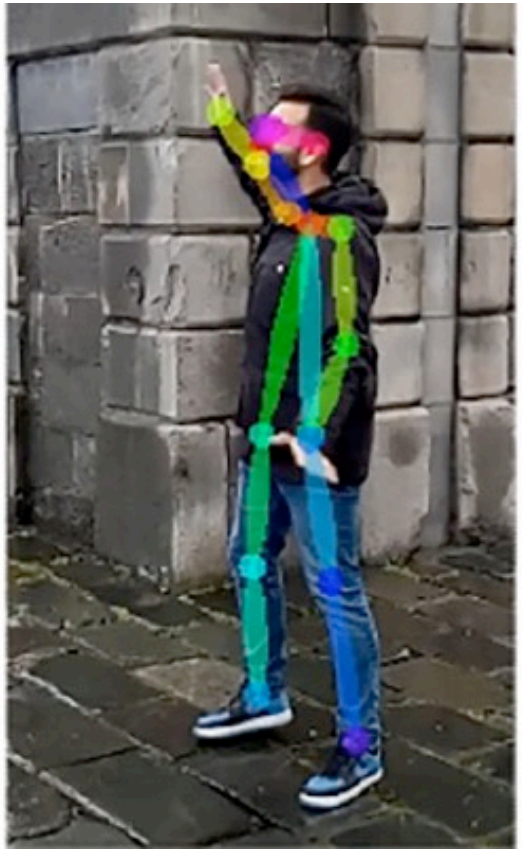
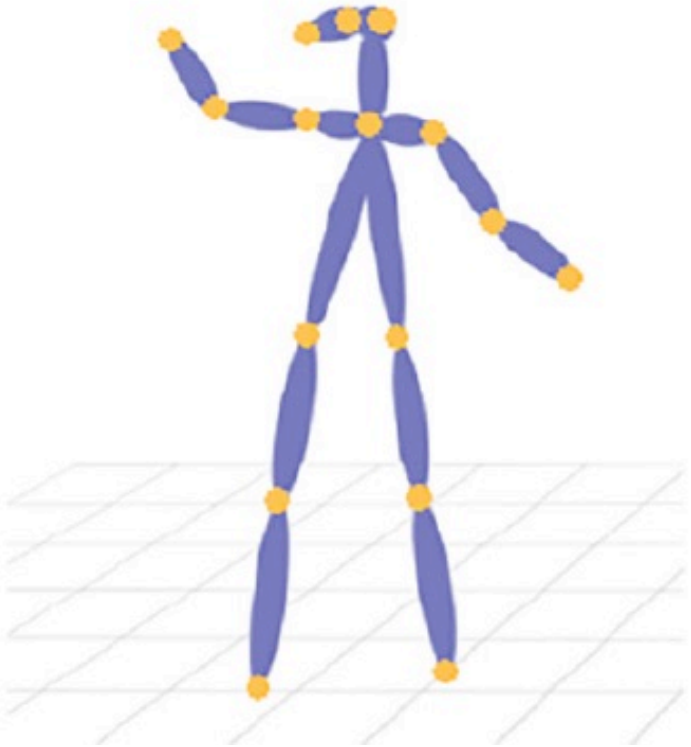
Moynihan, Matthew; Pagés, Rafael; Smolic, Aljosa
A Self-regulating Spatio-Temporal Filter for Volumetric Video Point
1182 , pp. 391-408, Springer International Publishing, 2020, ISBN: 978-3-030-41590-7.

2D Pose Estimation by CNN

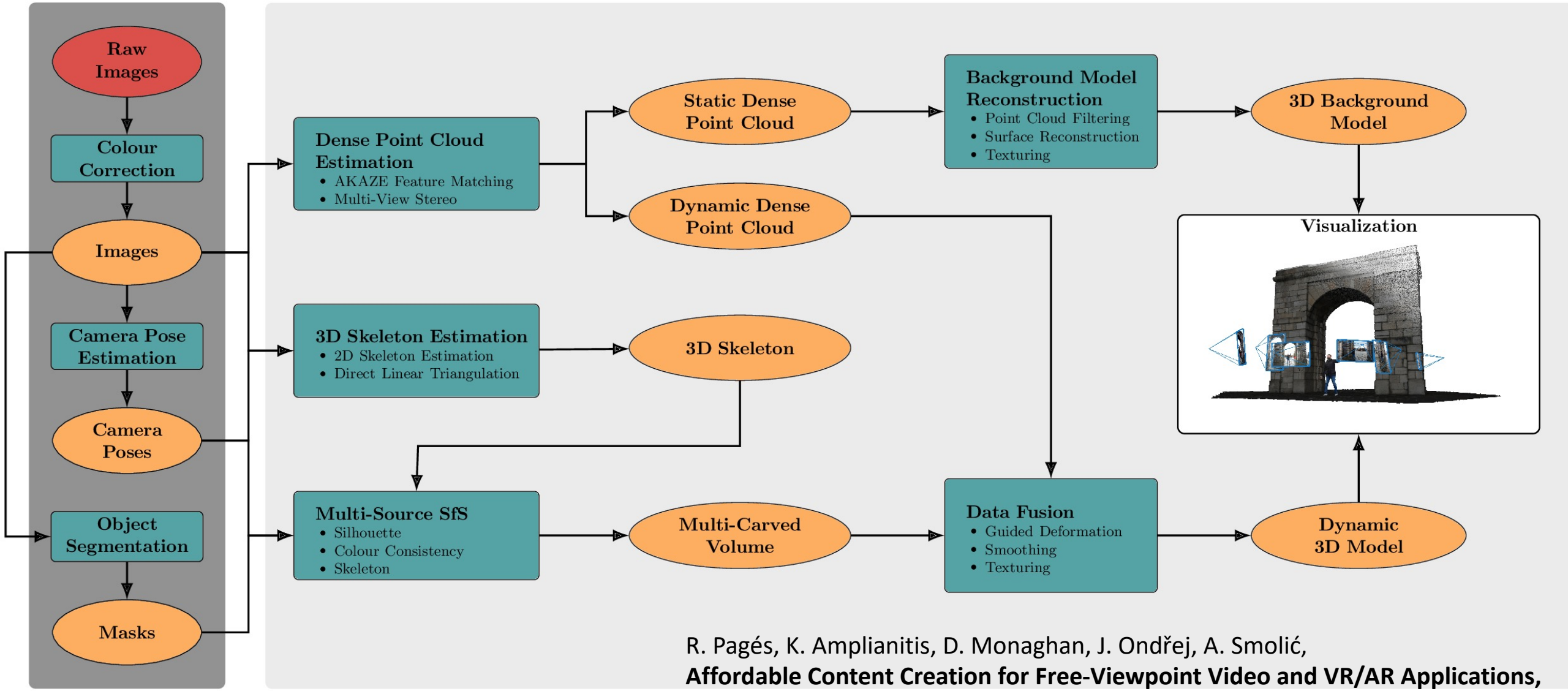
Realtime Multi-person 2D Pose Estimation using Part Affinity Fields
Zhe Cao, Tomas Simon, Shih-En Wei, Yaser Sheikh
CVPR 2017 **(Oral)**
https://people.eecs.berkeley.edu/~zhecao/

3D Pose Estimation by Multiview



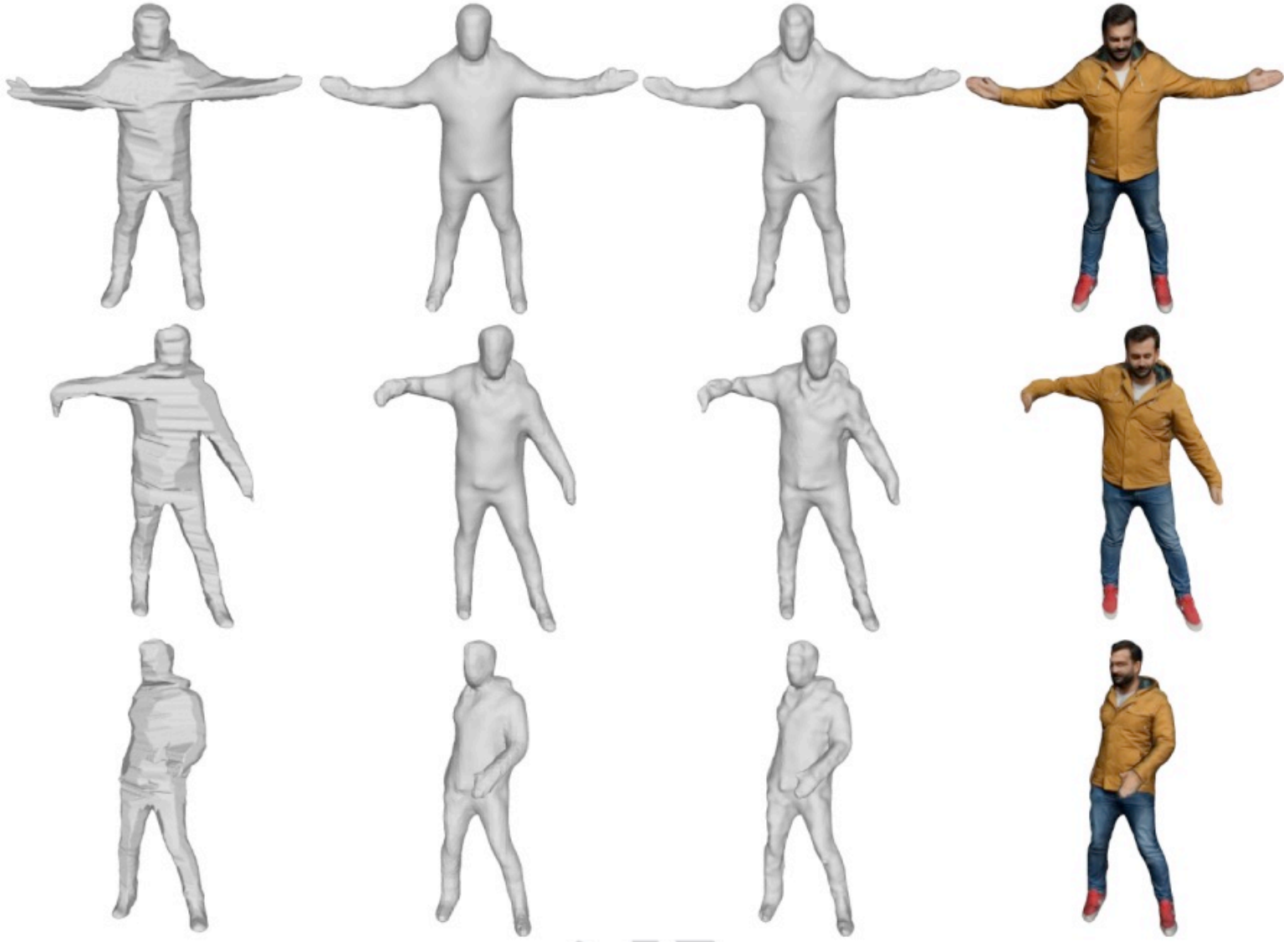



System Overview



R. Pagés, K. Amplianitis, D. Monaghan, J. Ondřej, A. Smolić,
Affordable Content Creation for Free-Viewpoint Video and VR/AR Applications,
J. Vis. Commun. Image R. (2018), doi: https://doi.org/10.1016/j.jvcir.2018.03.012

Improvements of Different Steps



Making Volumetric Video Mainstream

VOLOGRAMS


TORONTO RAPTORS
AIR CANADA CENTRE
EXPERIENCE intel


THE SOMBRERO
BANK

123017-Volumetric-16x9_1


Microsoft
Pearson

4DVIEWS

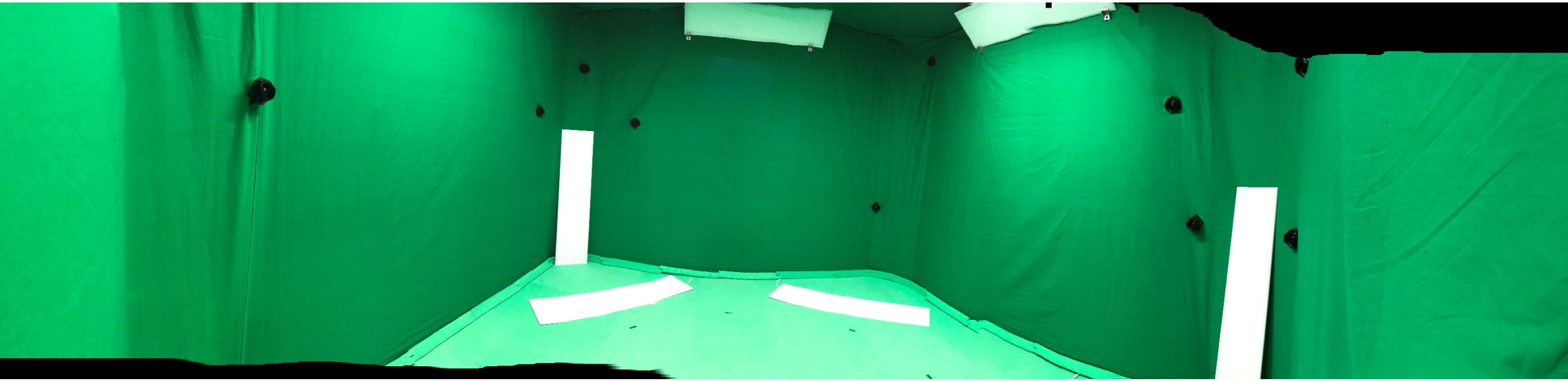
RAISE VIRTUAL
TO REALITY


4DV Center
4DV Data Manager
DELL

8i.com

https://techcrunch.com/2017/02/13/time-warner-leads-27m-investment-in-celebrity-hologram-company-8i/

VV for VR/AR Content Creation



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FMX 2018 APP

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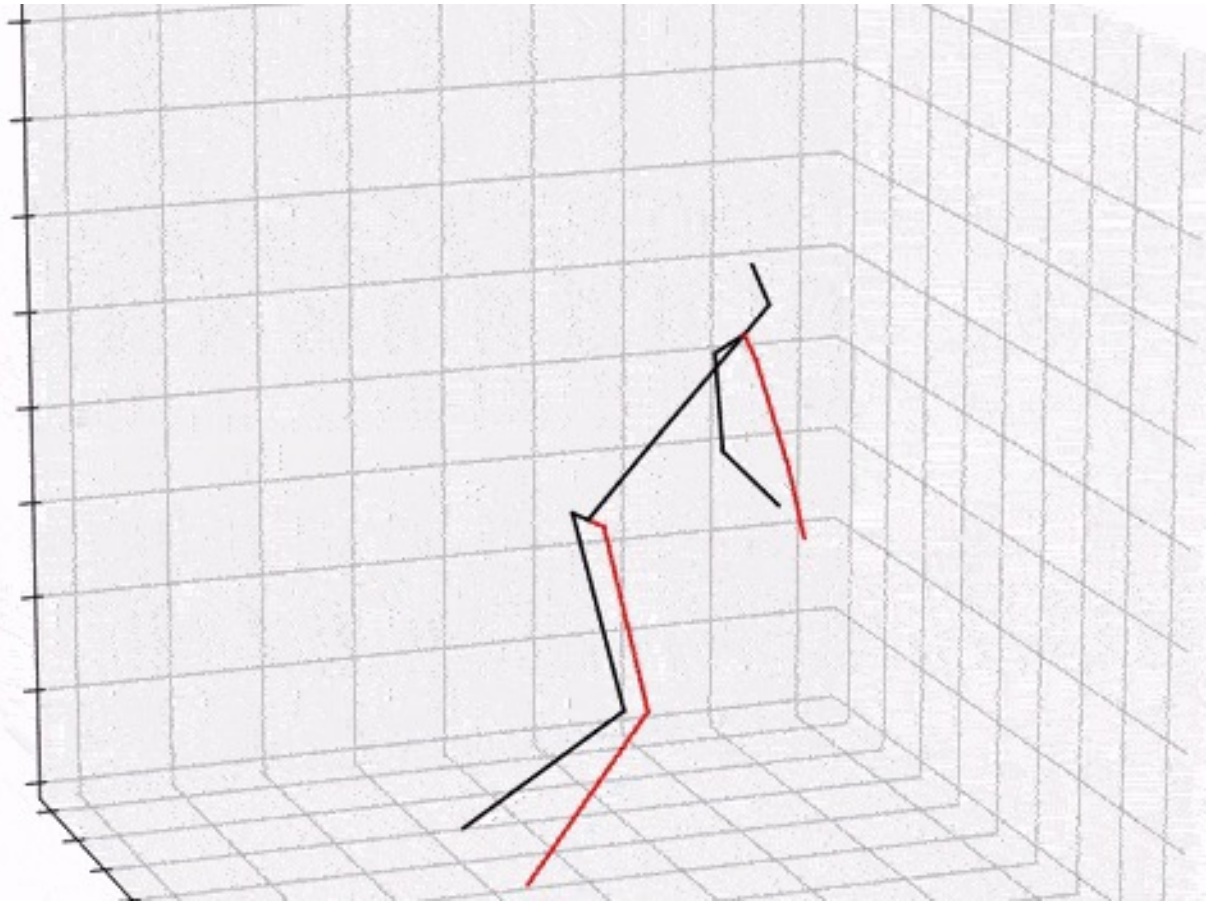
3D Deep Learning

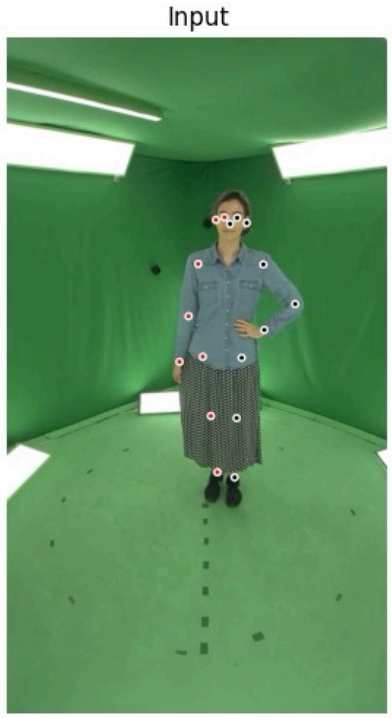
Professor Aljosa Smolic
SFI Research Professor of Creative Technologies

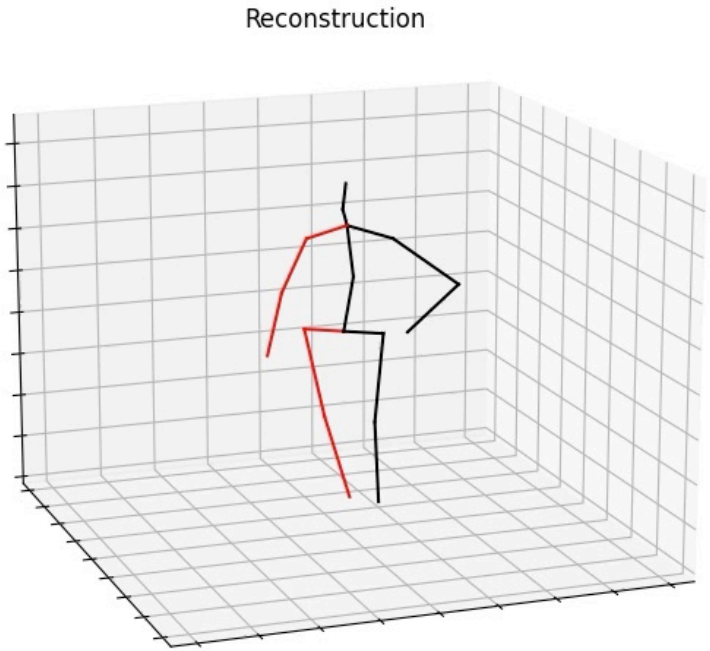
3D Deep Learning



3D human pose estimation in video with temporal convolutions and semi-supervised training
Pavllo, Dario and Feichtenhofer, Christoph and Grangier, David and Auli, Michael
CVPR 2019

3D Deep Learning





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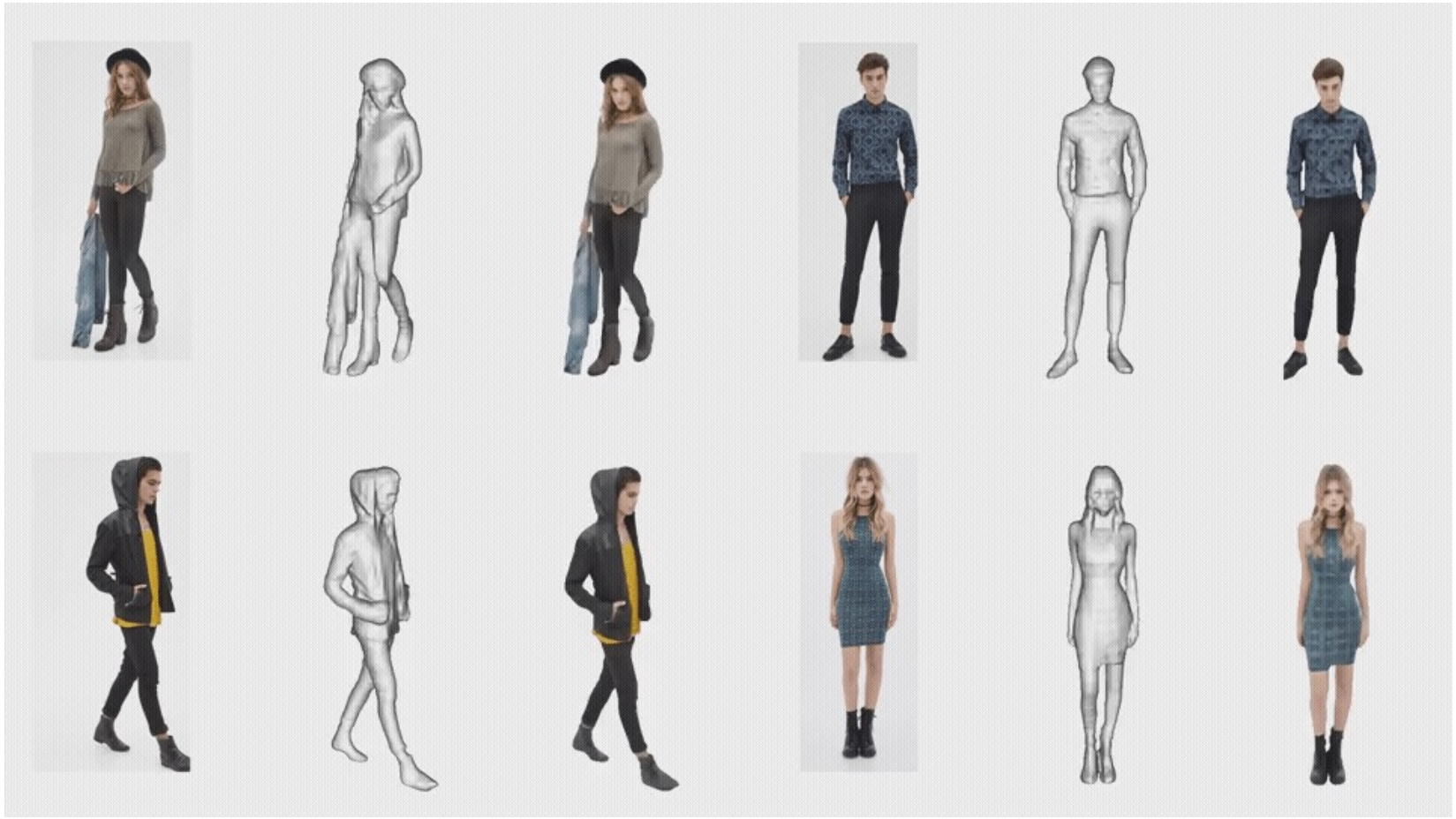
3D Deep Learning



Saito, S., Simon, T., Saragih, J. and Joo, H.
PIFuHD: Multi-Level Pixel Aligned Implicit Function for High-Resolution 3D Human Digitization
CVPR 2020

3D Deep Learning

Ruilong Li, Yuliang Xiu, Shunsuke Saito, Zeng Huang, Kyle Olszewski, Hao Li
MonoPort: Monocular Real-Time Volumetric Performance Capture
ECCV 2020


VOLOCRAMS

Making Volumetric Video Mainstream

VOLOGRAMS

VOLOGRAMS

Volu: Volumetric video content creation with a single mobile phone, available to everyone!

https://www.volograms.com

https://youtu.be/mlADjAIlSYs

https://www.volograms.com/volu

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V-SENSE

Volumetric Video Pipeline
Coding, Streaming, Quality Assessment

Professor Aljosa Smolic
SFI Research Professor of Creative Technologies

3D Mesh Resolution

50k polys/frame
~1GB / minute

15k polys/frame
~400MB / minute

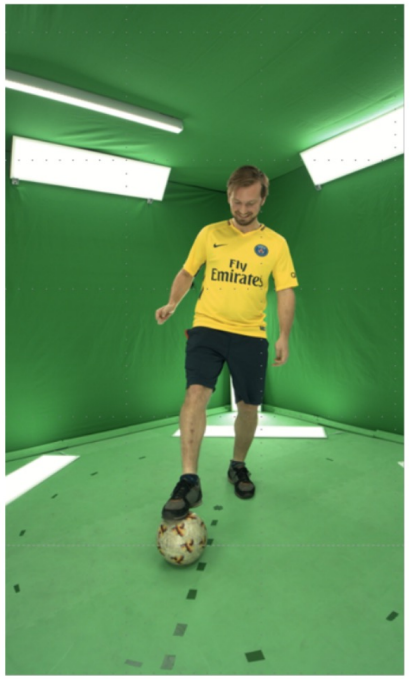
4k polys/frame
~150MB / minute

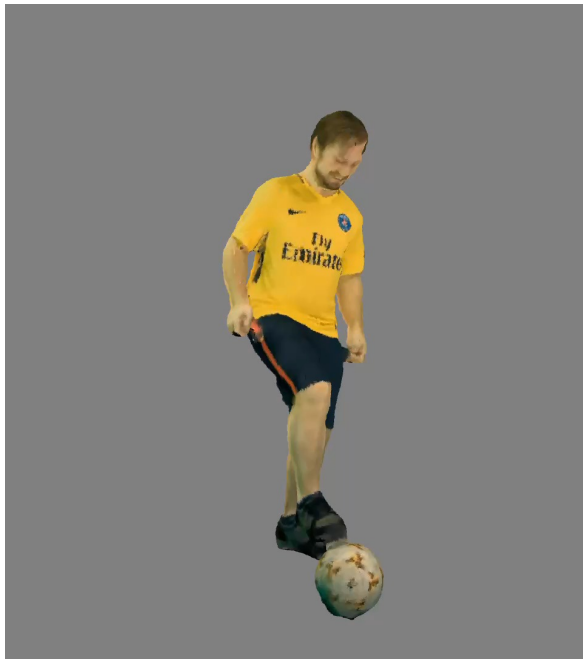
VOLOGRAMS

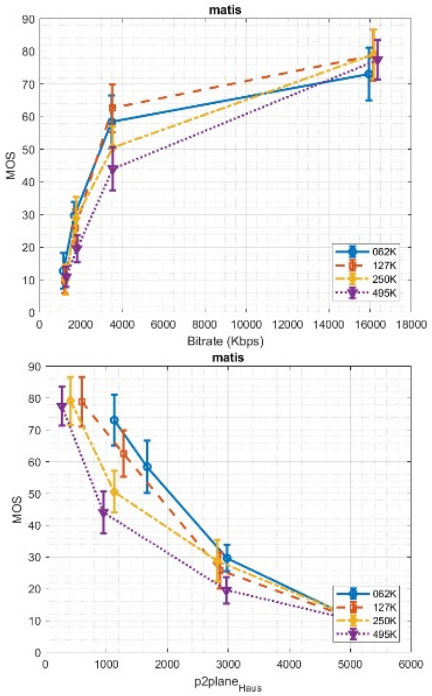
Content Delivery Pipeline for Volumetric Video

- From content acquisition to display and quality assessment, several steps of the content delivery pipeline for free-viewpoint videos are designed and analysed.

VV Acquisition | Processing | Compression | Streaming | Display | Quality Assessment







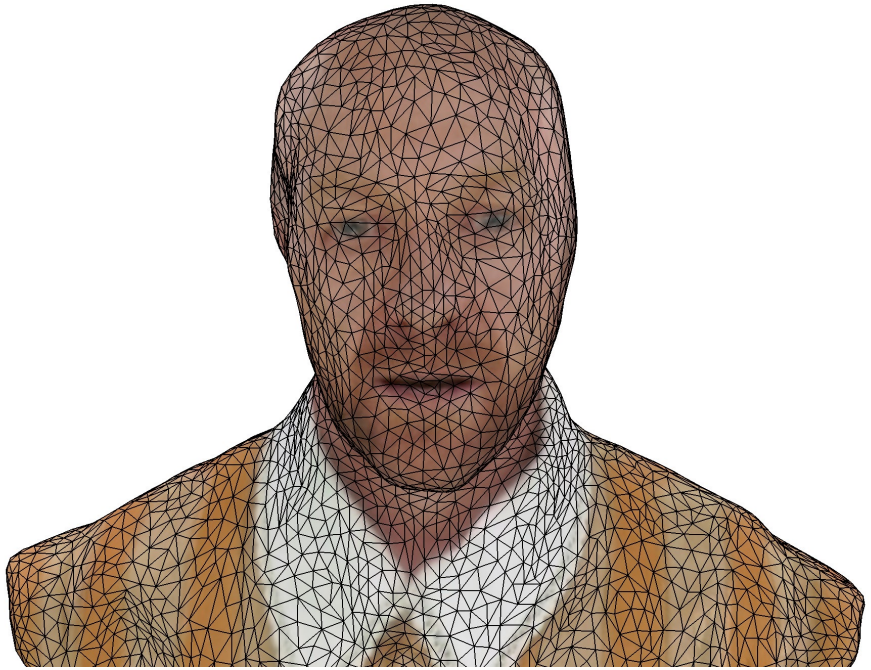
- Zerman, Emin; Gao, Pan; Ozcinar, Cagri; Smolic, Aljosa; "*Subjective and objective quality assessment for volumetric video compression*", **IS&T Electronic Imaging, Image Quality and System Performance XVI, 2019**.

Volumetric Video

How is it stored?

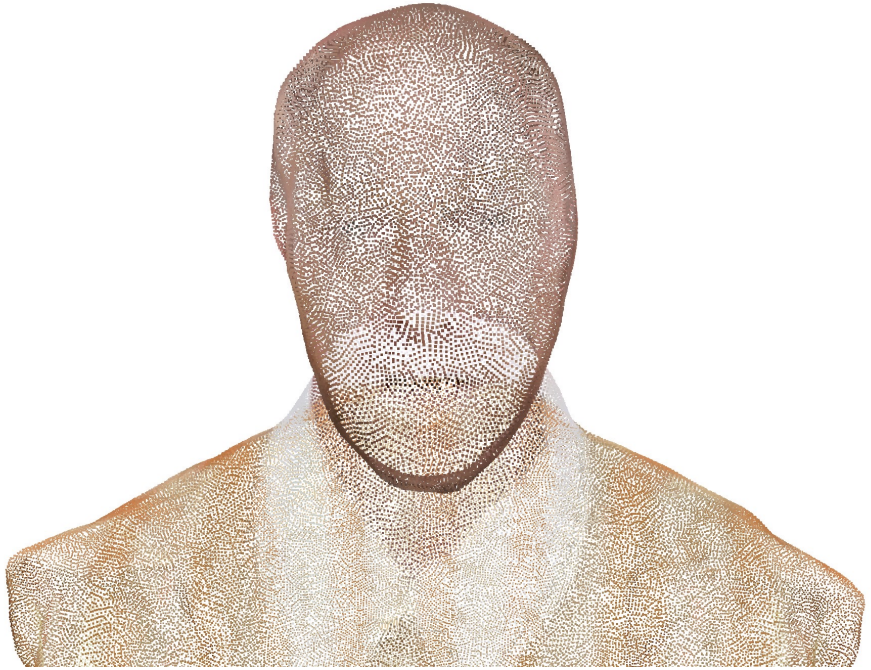
Textured polygonal meshes

- Vertices and Faces
- Texture atlas



Coloured point clouds

- Points
- Attributes (e.g., colour, normal, etc.)



Related Work

Quality assessment

Polygonal meshes:

- Doumanoglou et al. (2019) and
  Christaki et al. (201
  different open sour
  compression algorit

- Google's Draco was found the best performing mesh compression method, among:
  - Corto
  - Draco
  - O3DGC
  - OpenCTM

Coloured

clouds

- d Alexiou et al. (2019)
  nance of MPEG point
  methods on static
  clouds.

- Zerman et al. (
) and Gonçalvez et al.
  2 (i.e., V-PCC).

  TMC2) was found to
  erforming method.

There are **no** publicly available large QA databases for VV which can be used for understanding of QA for VV!

Textured meshes and point clouds were **not** compared in the literature!

Creating vsenseVVDB2 Database

Both textured meshes and coloured PCs

Only coloured point clouds

V-SENSE Data

8i Point Clouds

(a) AxeGuy [v:25K / p:405K]

(b) LubnaFriends [v:25K / p:402K]

(c) Rafa2 [v:25K / p:406K]

(d) Matis [v:25K / p:406K]

(e) Longdress [p:765K]

(f) Loot [p:784K]

(g) Redandblack [p:729K]

(h) Soldier [p:1.06M]

Zerman, Emin; Ozcinar, Cagri; Gao, Pan; Smolic, Aljosa

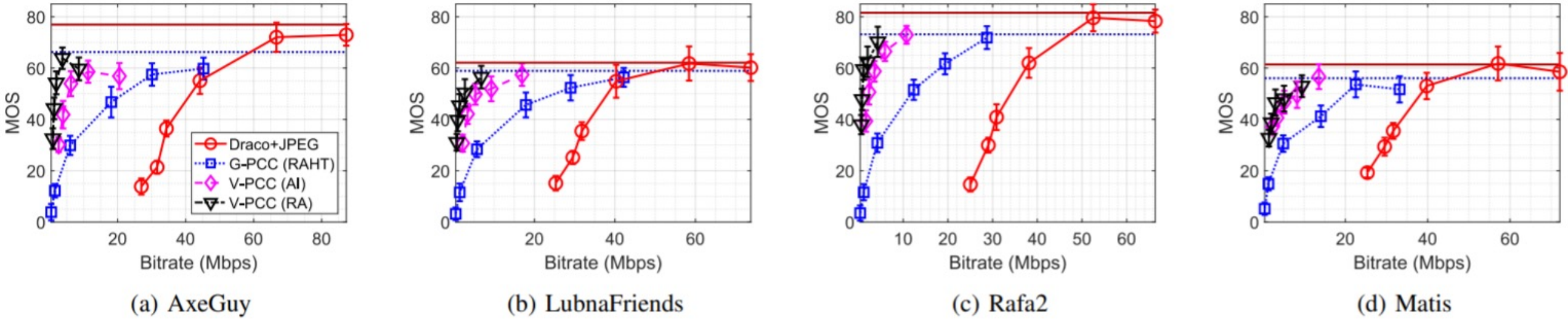
Textured Mesh vs Coloured Point Cloud: A Subjective Study for Volumetric Video Compression

Twelfth International Conference on Quality of Multimedia Experience (QoMEX), 2020, IEEE Athlone, Ireland.

Results

Mesh vs. Point Cloud

Textured mesh seems to be better than point clouds in high-bitrate cases, whereas point cloud compression is better in limited bitrate cases.



Zerman, Emin; Ozcinar, Cagri; Gao, Pan; Smolic, Aljosa

Textured Mesh vs Coloured Point Cloud: A Subjective Study for Volumetric Video Compression

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V-SENSE

Creative Experiments Immersive Storytelling in XR

Professor Aljosa Smolic

SFI Research Professor of Creative Technologies

V-SENSE Creative Experiments

- **Engage with creative community**
- **Showcase, prototype and test technology in real creative productions**
- **Visibility, impact, proof-of-concept, feedback**

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Trinity Long Room VR/AR Project

Jonathan Swift in Virtual and Augmented Reality

Jonathan Swift in Virtual and Augmented Reality

Problem: How to enrich the visitor experience visitor experience in the Trinity Long Room?

Jonathan Swift in Virtual and Augmented Reality

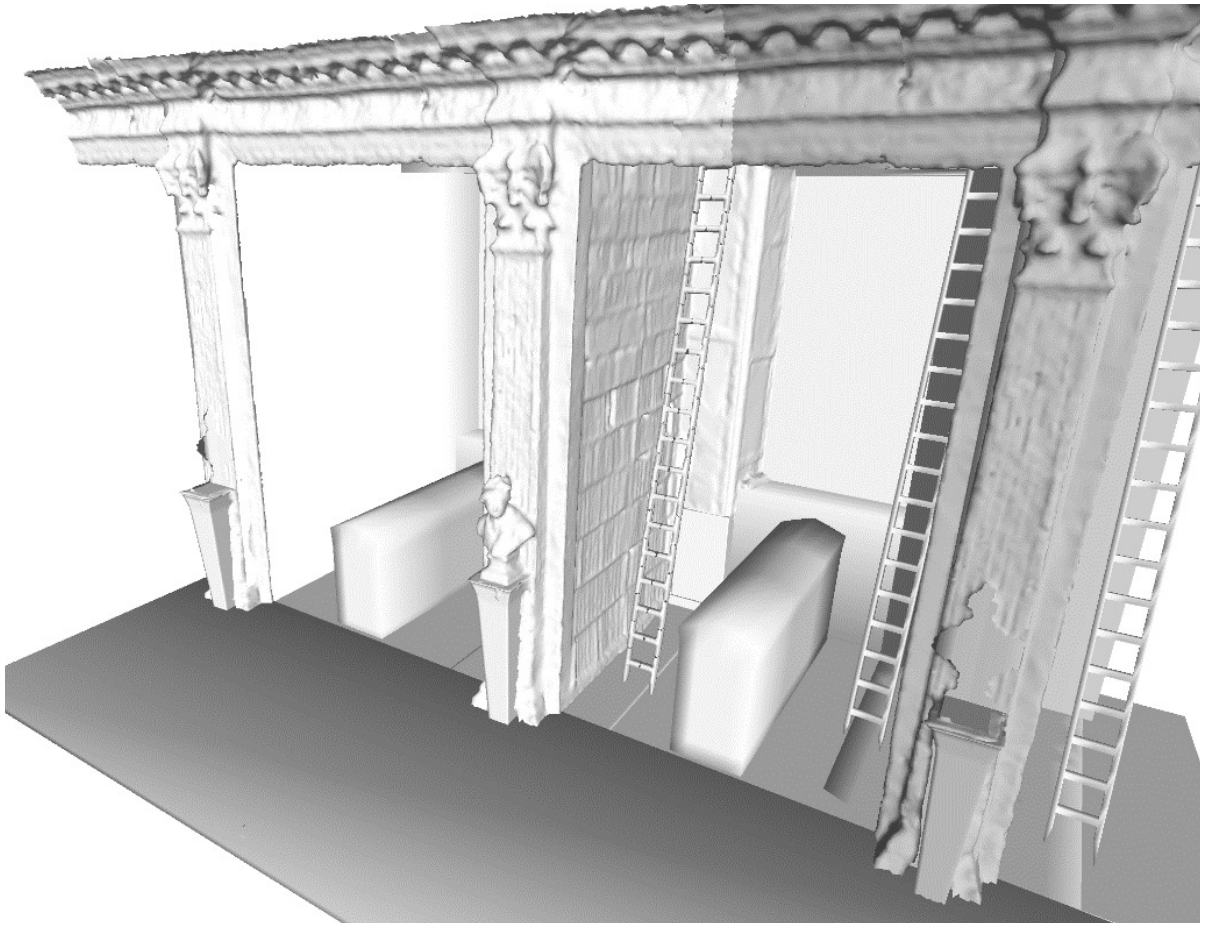
Multi-view Green Screen capture studio

Jonathan Swift in Virtual and Augmented Reality

Dynamic volumetric reconstruction of actor

Jonathan Swift in Virtual and Augmented Reality

Static reconstruction of architecture

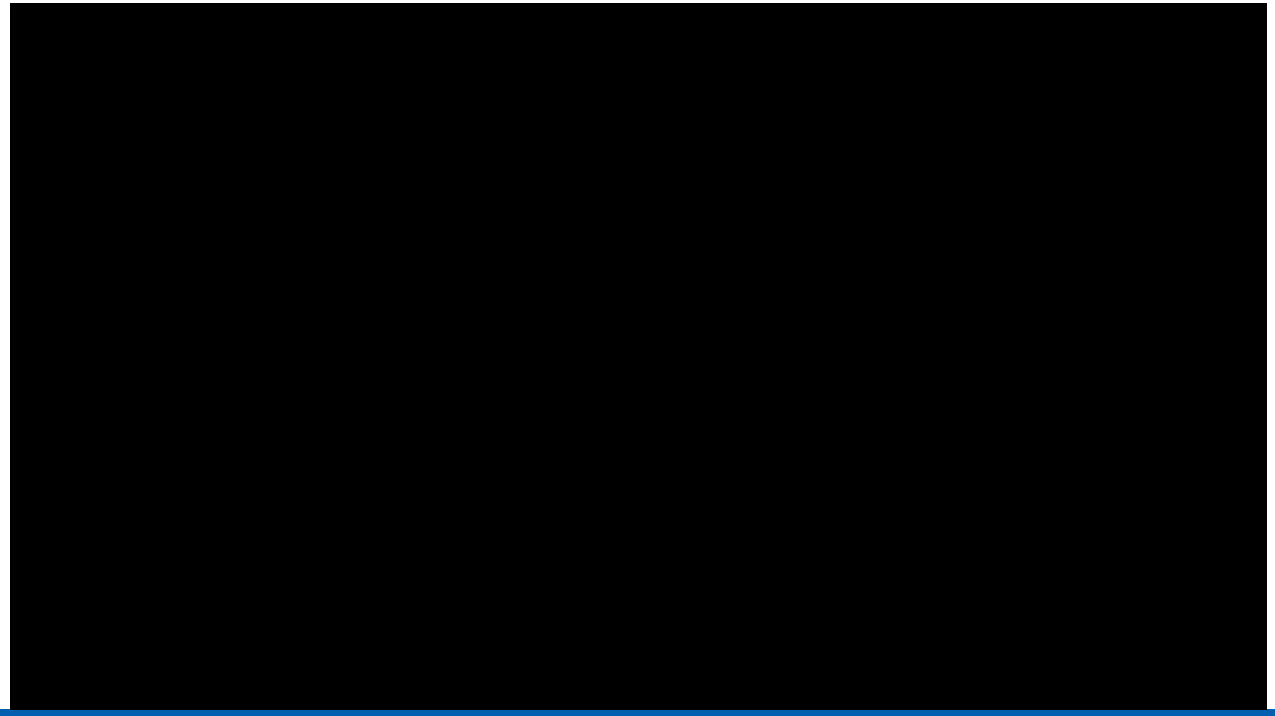


Cross-Reality (XR) Technology

Augmented and virtual reality experiences at V-SENSE

Augmented Reality

Virtual Reality



Jonathan Swift in Virtual and Augmented Reality

Completed AR Prototype: Mobile

Jonathan Swift in Virtual and Augmented Reality

Completed AR Prototype: Mobile

*O'Dwyer, Néill; Zerman, Emin; Young, Gareth W.; Smolic, Aljosa; Dunne, Siobhán; Shenton, Helen, "**Volumetric Video in Augmented Reality Applications for Museological Narratives: A user study for the Long Room in the Library of Trinity College Dublin**", Journal on Computing and Cultural Heritage, 2021.*

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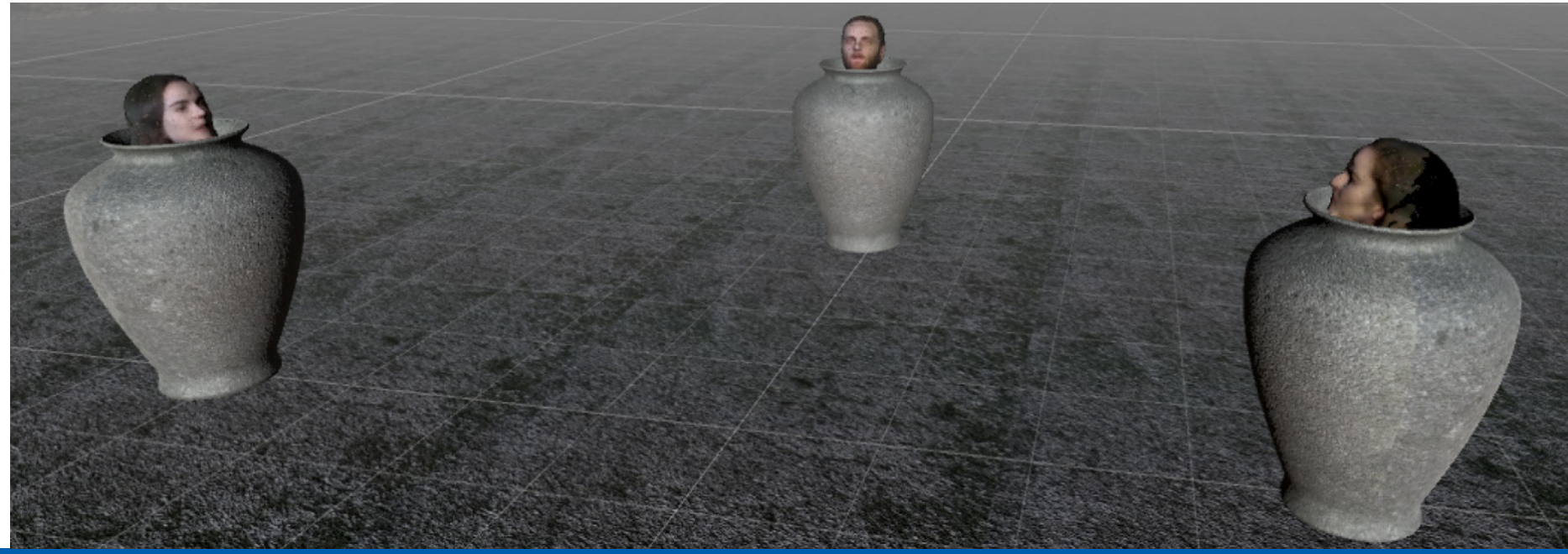
XR Play
After Samuel Beckett

XR Play, After Samuel Beckett

VR Play, After Samuel Beckett

A reinterpretation of Samuel Beckett's *Play* in Virtual Reality

With Prof. Nicholas Johnson, Dept. of Drama
Won NEM VR Art Award, NEM Summit 2017



Environment in VR

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VOLOGRAMS

Augmented Play, After Samuel Beckett

THE IRISH TIMES
Thursday, September 12, 2019

Bringing Beckett to life through augmented reality

Marie Boran

TCD spinout's technology could enable us to generate a projection of ourselves

Fans of Samuel Beckett are likely not enamoured with the fact that Timothy Ferriss's The 4-Hour Workweek and other tech entrepreneur-oriented bestsellers lifted the "fail better" quote from a pretty bleak text and turned it into a glib Silicon Valley inspirational quote. But just because Beckett had a dark worldview doesn't mean he didn't love to work with technology.

In fact, the playwright was something of an innovator, says Nicholas Johnson, Beckett scholar and assistant professor in the Department of Drama at Trinity College Dublin. Johnson says he likes to think Beckett would have approved of an augmented reality (AR) version of the 1963 work Play that debuted last week, using unique motion capture technology developed by Trinity spinout Volograms.

I wasn't sure what to expect but upon arrival I was greeted by the sight of a couple of people walking around wearing AR headsets. Where was the play? It turns out they were watching it. Volograms co-founder and chief operating officer Konstantinos Amplianitis explained that the headset wearers were experiencing different, separate versions of Play, which had been directed by Johnson and captured as a dynamic 3D scan of the actors.

Obviously, I needed to try it out. The headset allows you to walk around the three actors (agitated talking heads in urns, just how Beckett liked). As you turn your gaze on one, it begins to talk, move your line of sight to another head and they start to speak. As the viewer your gaze controls the narrative and therefore becomes part of the experience. I imagine this non-linear flow of the play works as a Beckettian device; you walk away from it having experienced a unique version and can make of it what you will.

What was most impressive was the detail of the actors' faces, allowing the viewer to walk up close and around the urns in 360 degrees, seeing Play in a way it has never been experienced before. Johnson said to the audience that had Beckett been there, he might have sat quietly in a corner, keeping to himself, but he would have enjoyed it all the same.

"We were really happy to see the reaction from the Trinity drama department," says Volograms chief executive Rafael Pagés. "Beckett was always innovating and adapting his work to new fields, so we like thinking that he would have been our biggest supporter."

"We have been very lucky to participate in a project like this, which involves technology, creativity and art. The project is as a collaboration between V-Sense, a leading visual computing research group at Trinity, the Trinity Centre for Beckett Studies, and Volograms."

Now settled in the Guinness Enterprise Centre, Volograms – although only one year old – has raised €850,000 with the support of Atlantic Bridge ventures through the University Bridge Fund and Enterprise Ireland. These funds were used to build the team and to bring the technology to a commercial level.

And a vologram isn't simply a 3D head: "A vologram is a digital volumetric representation of a human performance," explains Pagés. "In other words: we film a person talking or acting, and then we create a dynamic 3D scan of him or her."

"One of the biggest misconceptions we face is that people think we 3D scan a static person and then an artist animates it, which is not the case: we capture the performance as it is, with every little detail, and it is done automatically," he adds.

"We are now taking an extra step and making this technology available to other studios. We are pitching our vision to investors so they can help us make it a reality."

Vologram tech doesn't require a headset. The start-up has also worked with Virtual Reality Ireland to create an AR tourism app for visitors to Manorhamilton Castle in Co Leitrim. Using the tablet supplied, visitors will "see" the stern looking ghost of Sir Frederick Hamilton pop up and tell them a little bit about the history of the castle.

I ask Pagés if he has his own vologram. "Of course I do. We all do," he says with a laugh. Then he takes out his phone, opens the app, at which point a mini Rafael pops up. This is what many smartphone owners would love, I say. A little vologram of themselves to take selfies with.

"Our volograms are compatible with Snapchat and Instagram. This means that you can capture somebody with our tech, and you don't need an augmented or virtual reality headset, or to download a specific app, you can directly see them and share them within Snapchat or Instagram."

"For example, if you are a brand who wants to show a vologram of a celebrity or a brand ambassador, we can create a Snapchat AR lens or an Instagram AR effect featuring that celebrity, so all your followers can take a picture next to him or her, and share it with their network," he adds.

"For now, we think that phones and tablets are the easiest and more accessible way to experience this content, but the future is definitely AR headsets that will look more like conventional glasses."

How can we get our own vologram?

"If you wanted to get one we would bring you into the studio and film you with 12 cameras pointing at you from different viewpoints," says Pagés.

"With these videos, we would be able to run our 3D reconstruction algorithms that generate a sequence of 3D models, 30 per second of video. Lastly, we take all those 3D models and compress them so you can play with it, integrate it into your own application, and share it on social media."

With a Beckett play and a tourism app under their belt, Pagés says the next step is to bring volumetric video capture closer to everyone, making it more accessible. It's already one step ahead of other companies in the same field because a vologram requires a low number of cameras to create its 3D captures.

"Unlike some other studios that use more than 100 cameras for 3D capture, ours lowers the barriers to entry for professionals. The key challenge for the company for the next year is not doing more projects ourselves, but to enable others to do projects using our technology."

So, no trying again or failing again for Volograms because they seem to be doing very well indeed. To utterly misquote Beckett, they must go on, they can go on, they'll go on.

> Beckett was always innovating and adapting his work to new fields, so we like thinking that he would have been our biggest supporter

Above and left: Researchers experiment to deliver Samuel Beckett in augmented reality for the first time. The project reinterprets Beckett in a way that is engaging for 21st century audiences, by using cutting-edge interactive digital media technologies. Guests put on a headset and explore the narrative by confronting Beckett's characters in AR. PHOTOGRAPHS: CHRIS BELLEW/FENNELL PHOTOGRAPHY

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Image Technology Echoes

Writer/Director: Lauren Moffat

V-SENSE Team: Matthew Moynihan, Iman Zolanvari, Neill O'Dwyer, Aljosa Smolic

Image Technology Echoes

https://vrkunst.dkb.de/en/

https://v-sense.scss.tcd.ie/creative-experiments/image-technology-echoes/

WINNER OF VR ART PRIZE

XR Ulysses, James Joyce

Neill O’Dwyer

Paul O’Hanrahan

Matthew Moynihan

Gareth Young

Aljosa Smolic

https://v-sense.scss.tcd.ie/research/mixed-reality-ulysses/

Conclusions

- **VV is a novel type of interactive and immersive media**
- **Enables novel forms of storytelling and communication**
- **Technology is mature enough to enter broad application**
- **Content creation may improve further through deep learning**
- **Coding, streaming, quality assessment need more work**
- **Real-time communication not yet mature enough => telepresence**

Trinity College Dublin

The University of Dublin

V-SENSE

Many Thanks

smolica@tcd.ie