visuAAL

Privacy-Aware and Acceptable Video-Based Technologies and Services for Active and Assisted Living

# Doctoral Seminar - Vienna

## ESR 13 - Privacy Preservation in Video-based AAL Applications

**Siddharth Ravi, University of Alicante**
**30 Nov 2023**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 861091".

Universitat d'Alacant
Universidad de Alicante
Project Coordinator

RWTH AACHEN UNIVERSITY

Stockholm University

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

TU WIEN

# The Promise and Perils of AAL:

## Empowering Users While Safeguarding Privacy

AAL technologies have **enormous potential** to improve the lives of older adults and persons with disabilities.

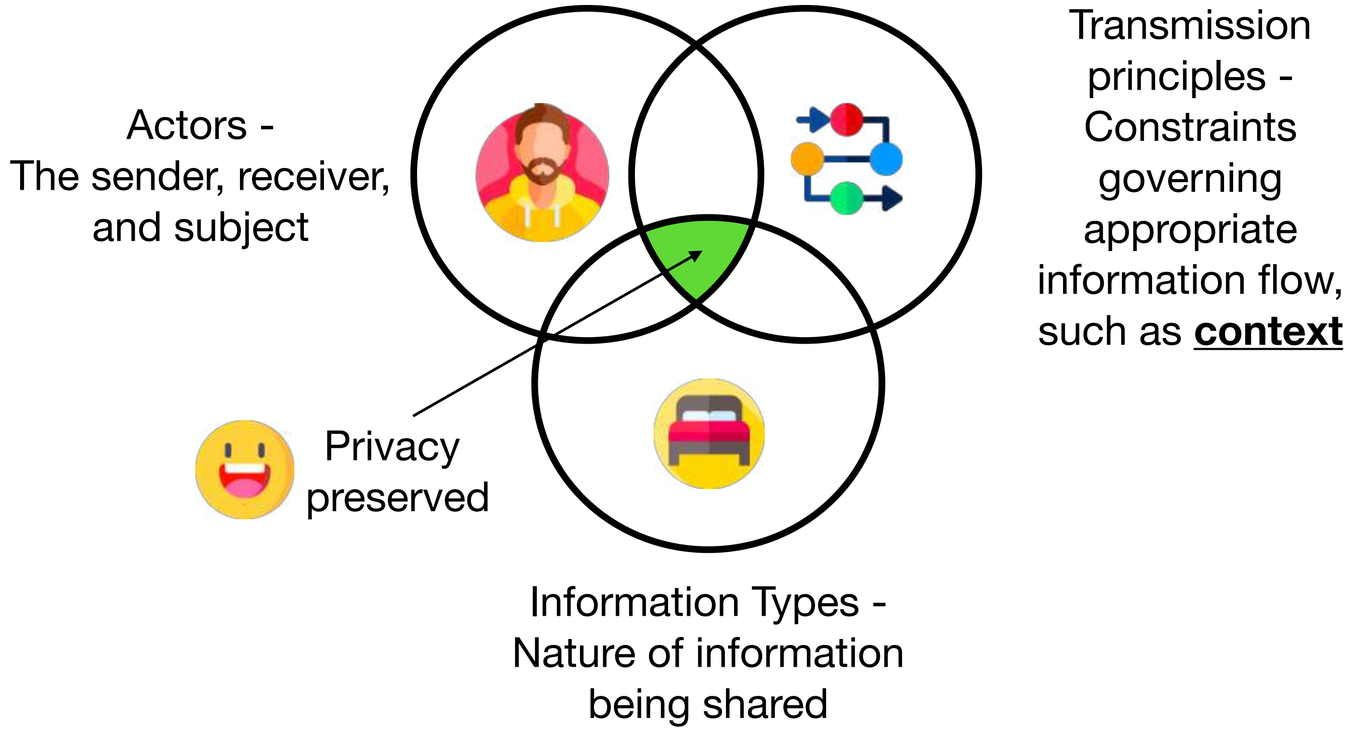
Widespread adoption of these technologies raise **privacy concerns.**

Providing **Privacy by Context** is key

# Privacy by Context

## Understanding Contextual Integrity

- Introduced in Nissenbaum (2009)
- Emphasizes that privacy is preserved when personal information flows align with the norms, expectations, and values of a specific social context.
- This idea, known as contextual integrity, highlights three main parameters:




Source: Nissenbaum, H. (2009). *Privacy in Context: Technology, Policy, and the Integrity of Social Life. Redwood City: Stanford University Press.* https://doi.org/10.1515/9780804772891

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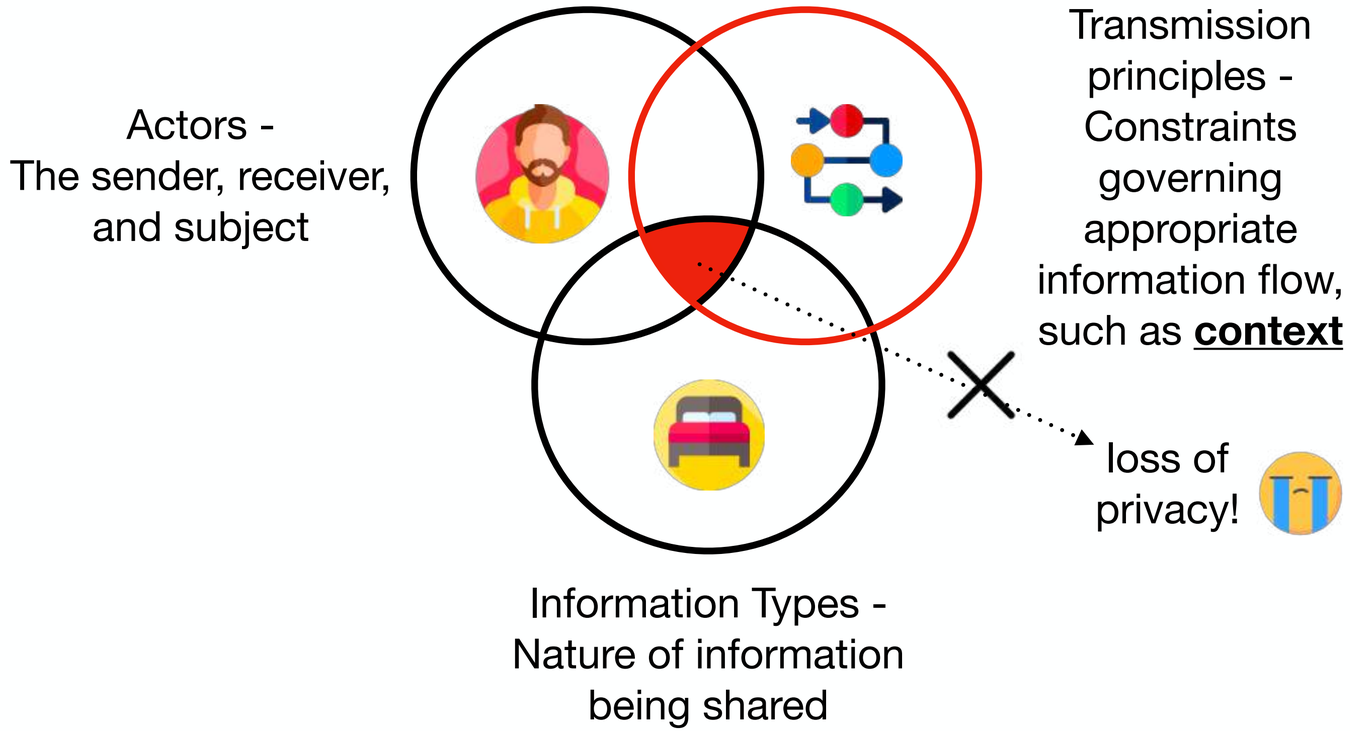


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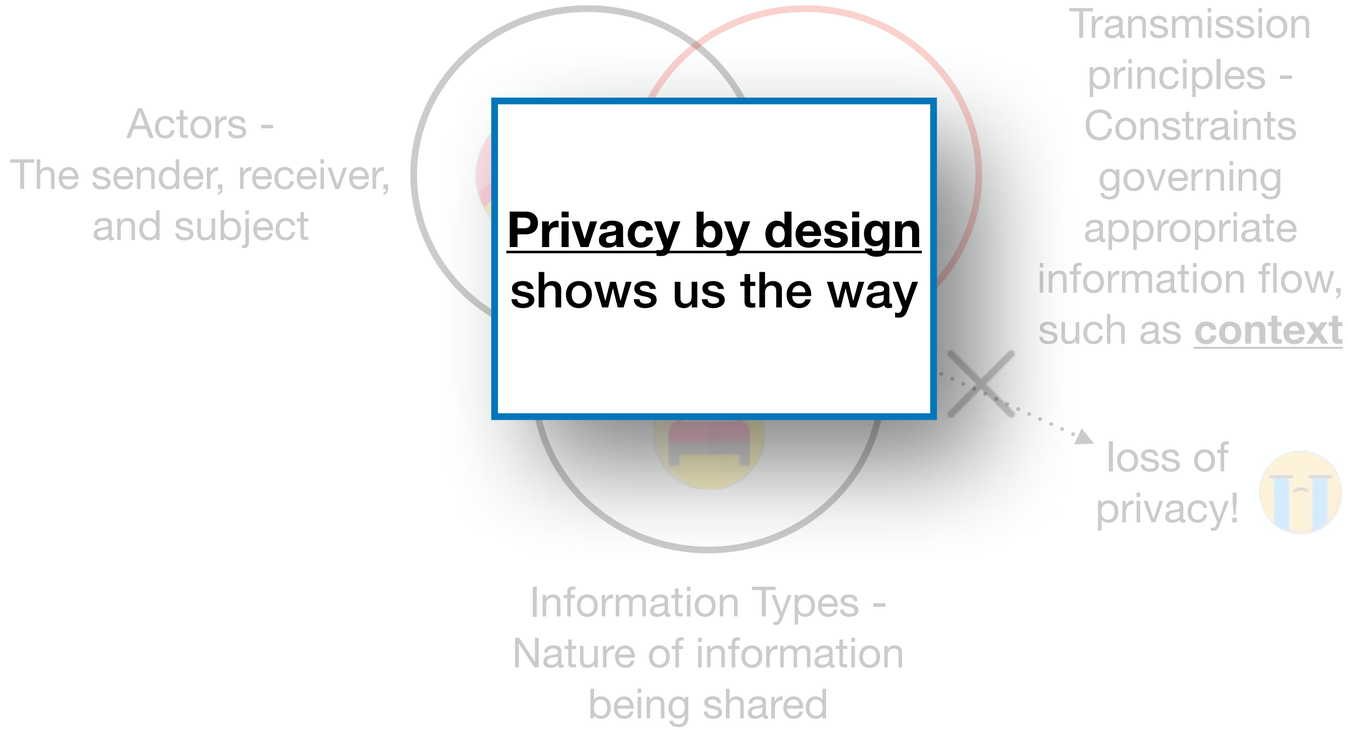


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Cavoukian, A. (2009). Privacy by design.

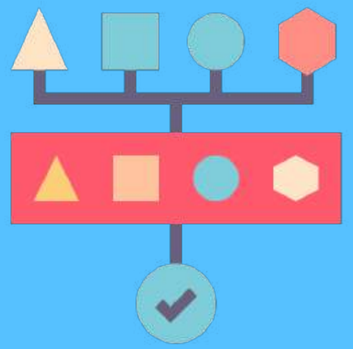
# Research Goal

Can we create an end-to-end private by design pipeline for contextual visual privacy preservation in AAL using omnidirectional RGB cameras, and which adheres to EU legal regulations?

# Research Questions

**RQ1**

Can we provide contextual visual privacy for individuals appearing in RGB images?



**RQ2**

Can we provide privacy to individuals appearing in zenithal-view omnidirectional camera images?

**RQ3**

Can a private by design pipeline be created for omnidirectional images that adheres to legal regulations?

# Research Questions

**RQ1**

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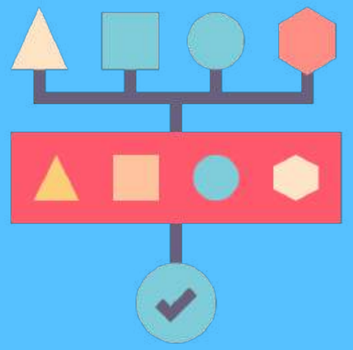

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RQ3

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# RQ1 Can we provide contextual visual privacy for individuals appearing in RGB images?

- Created a taxonomy of Visual Privacy Enhancing Technologies during literature review (Ravi et al., 2023).
- 5 major categories of importance highlighted.
- Connected to the taxonomy for privacy by design proposed in Mihailidis & Colonna (2020).

Multimedia Tools and Applications
https://doi.org/10.1007/s11042-023-15775-2

Check for updates

## A review on visual privacy preservation techniques for active and assisted living

Siddharth Ravi[1] · Pau Climent-Pérez[1] · Francisco Florez-Revuelta[1]

Received: 2 November 2022 / Revised: 27 March 2023 / Accepted: 2 May 2023


**Abstract**
This paper reviews the state of the art in visual privacy protection techniques, with particular attention paid to techniques applicable to the field of Active and Assisted Living (AAL). A novel taxonomy with which state-of-the-art visual privacy protection methods can be classified is introduced. Perceptual obfuscation methods, a category in this taxonomy, is highlighted. These are a category of visual privacy preservation techniques, particularly relevant when considering scenarios that come under video-based AAL monitoring. Obfuscation against machine learning models is also explored. A high-level classification scheme of privacy by design, as defined by experts in privacy and data protection law, is connected to the proposed taxonomy of visual privacy preservation techniques. Finally, we note open questions that exist in the field and introduce the reader to some exciting avenues for future research in the area of visual privacy.

**Keywords** Visual privacy preservation · Active and assisted living · Privacy by design · Perceptual obfuscation · Machine obfuscation · Facial de-identification

### 1 Introduction

Active and Assisted Living (AAL) systems aim to improve the quality of life for older adults and individuals with disabilities by leveraging information and communication tech-

*Sources:*
Ravi, S., Climent-Pérez, P., & Florez-Revuelta, F. A Review on Visual Privacy Preservation Techniques for Active and Assisted Living. *Multimedia Tools and Applications, 2023*
Mihaildis, A., & Colonna, L. (2020). A Methodological Approach to Privacy by Design within the Context of Lifelogging Technologies. *Rutgers Computer and Technology Law Journal, 46, 1.*

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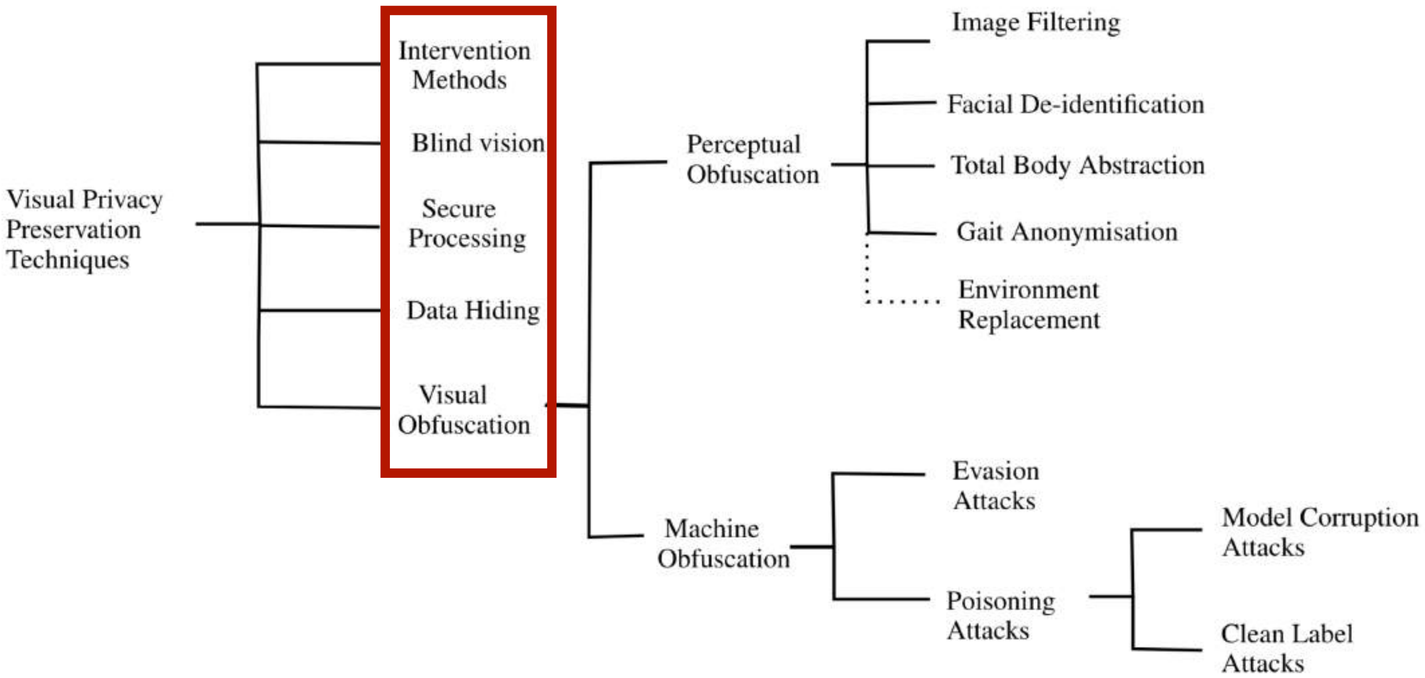


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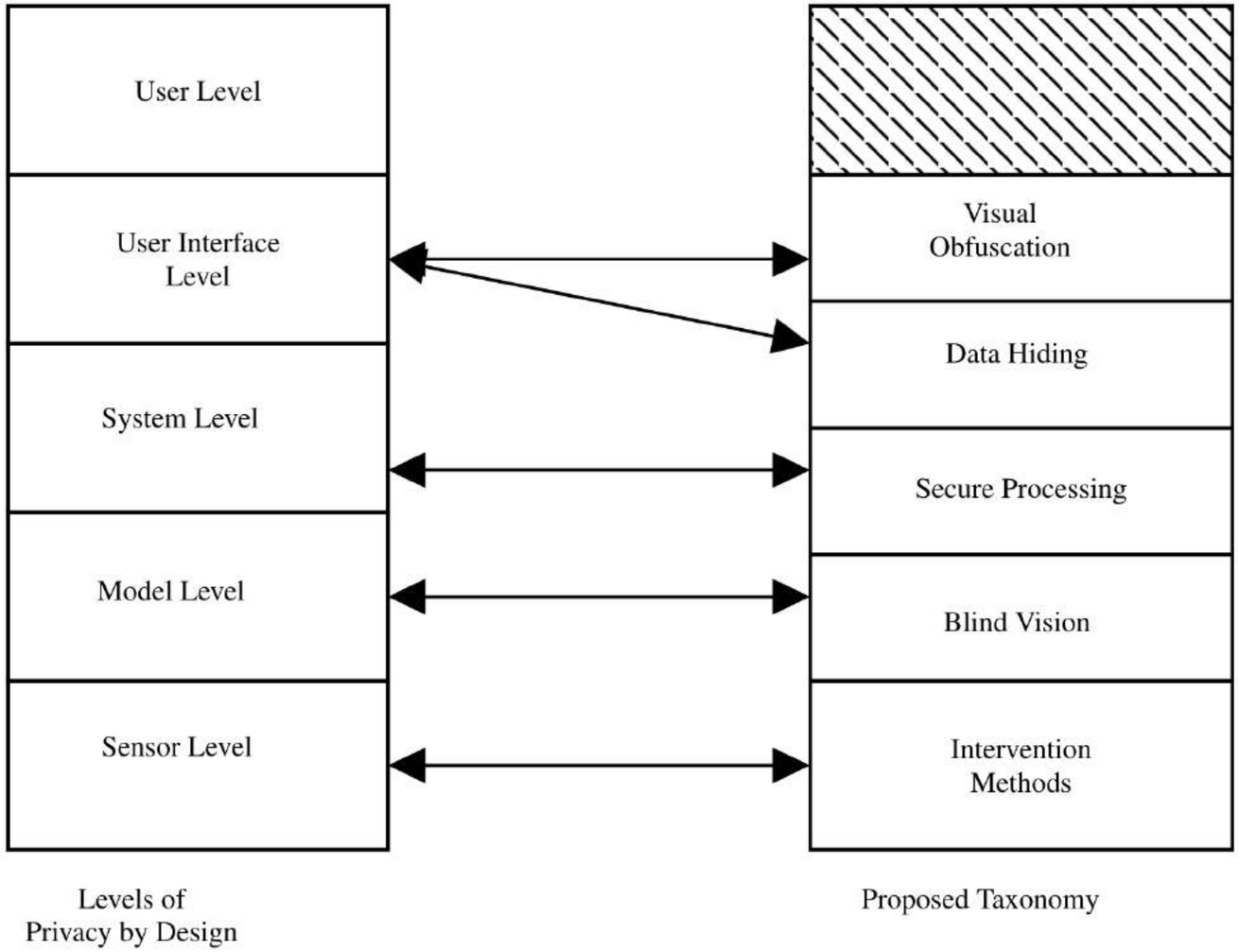
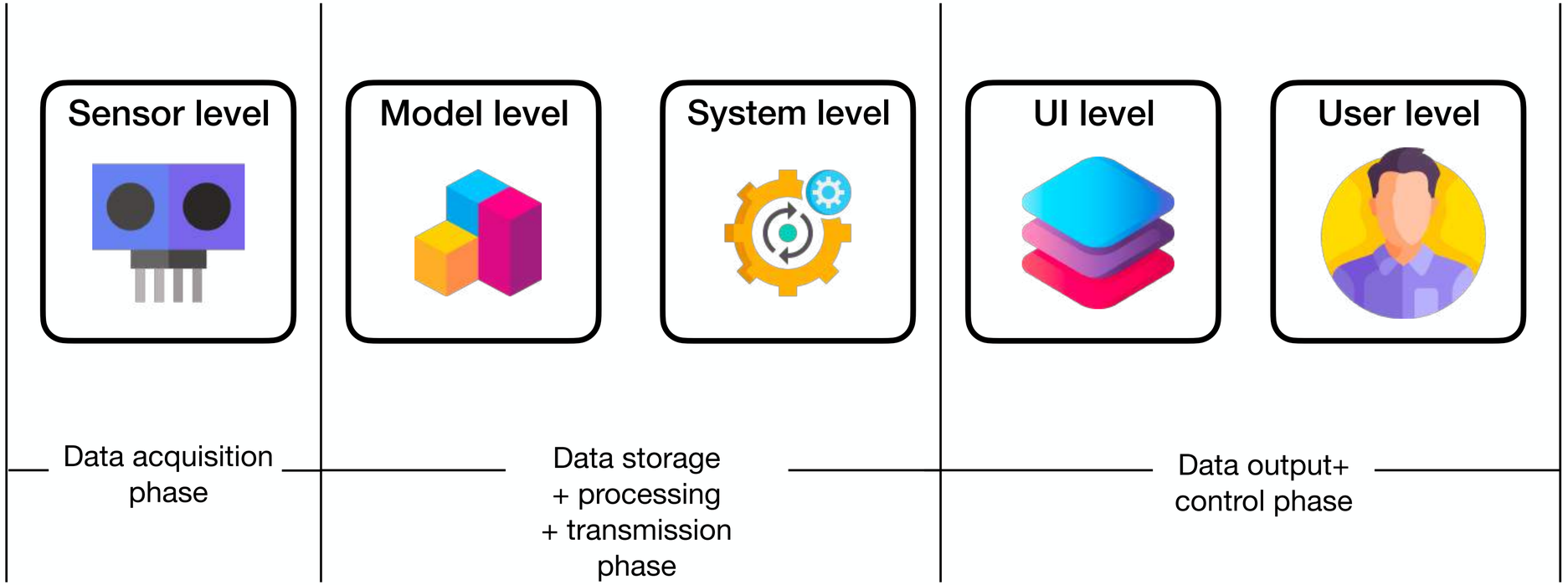
# Connecting taxonomies




*Source:* Ravi, S., Climent-Pérez, P., & Florez-Revuelta, F. A Review on Visual Privacy Preservation Techniques for Active and Assisted Living. *Multimedia Tools and Applications, 2023*

# Analysing design elements for visual Privacy by Design

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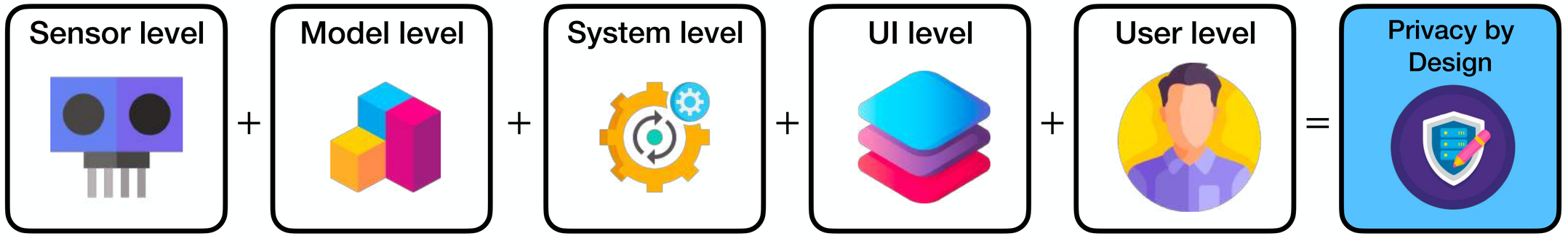
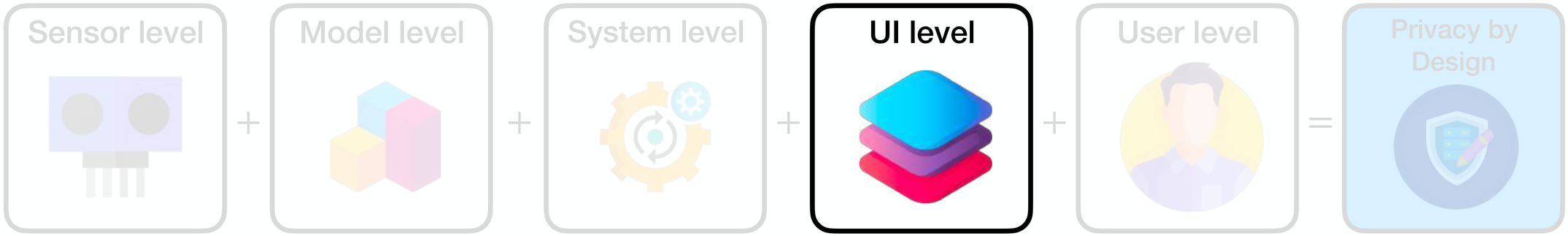



- Methods often show overlap between levels!
- Stitching together methods that fall under each level of the methodology should get us closer to PbD.

Source: Mihaildis, A., & Colonna, L. (2020). A Methodological Approach to Privacy by Design within the Context of Lifelogging Technologies. *Rutgers Computer and Technology Law Journal, 46, 1.*

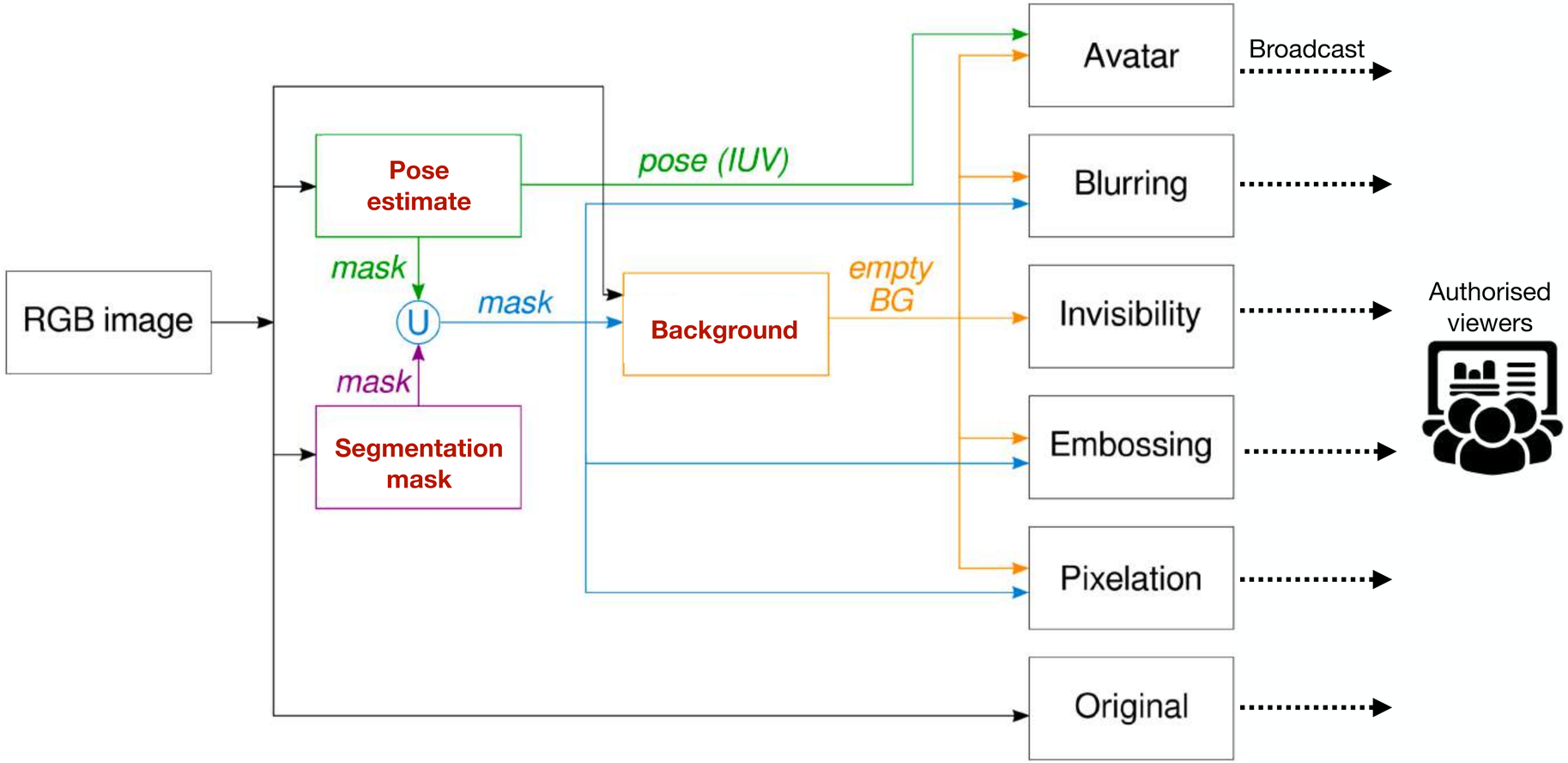
# Analysing design elements for visual Privacy by Design




- The level where data is presented to authorised viewers.
- Most visual obfuscation methods operate at this level
- Eg: The pipeline from Climent-Perez & Florez-Revuelta (2021)

Source: Climent-Pérez, P., & Florez-Revuelta, F. (2021). Protection of visual privacy in videos acquired with RGB cameras for active and assisted living applications. *Multimedia Tools and Applications*, *80*(15), 23649–23664.

# A pipeline for privacy preservation

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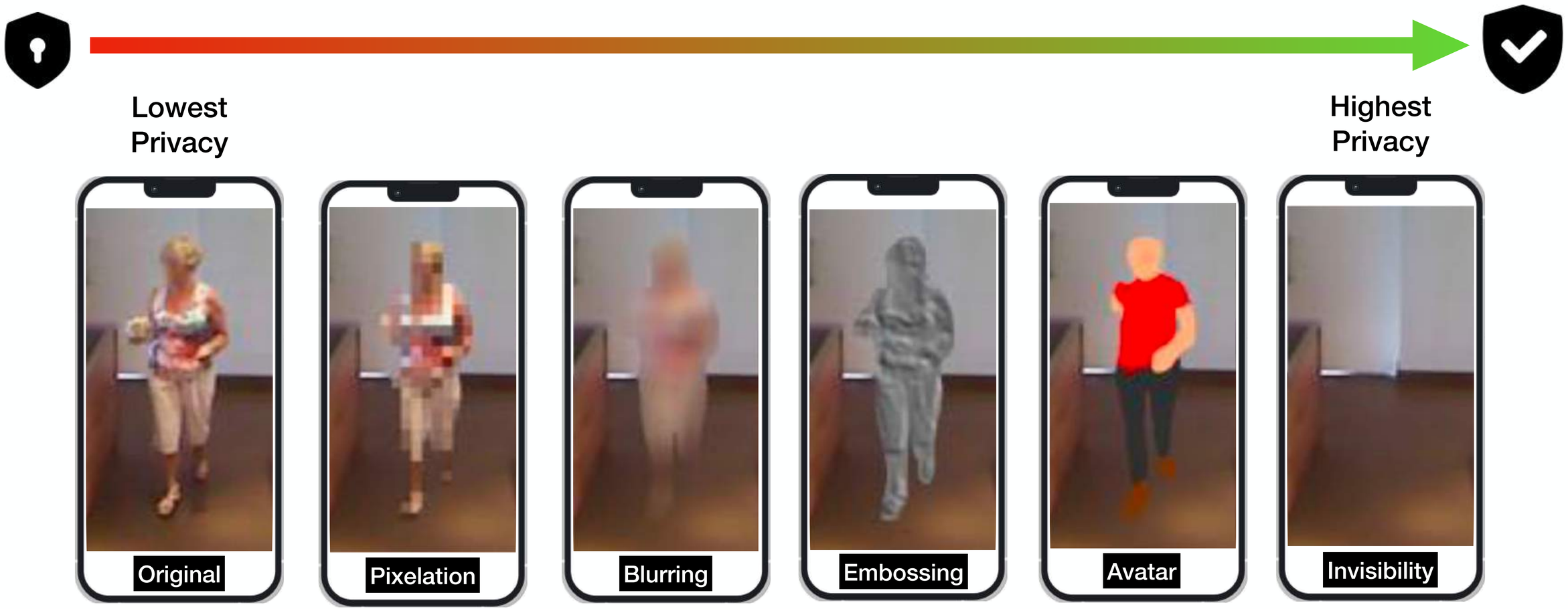
# Operating at the UI level

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Person facing away from camera
Obtrusive camera placement
Only part of the person observable
Occlusions

# Zenithal-view dioptric omnidirectional cameras offer a compelling alternative


Wide field of view - Just one camera enough to view an entire scene

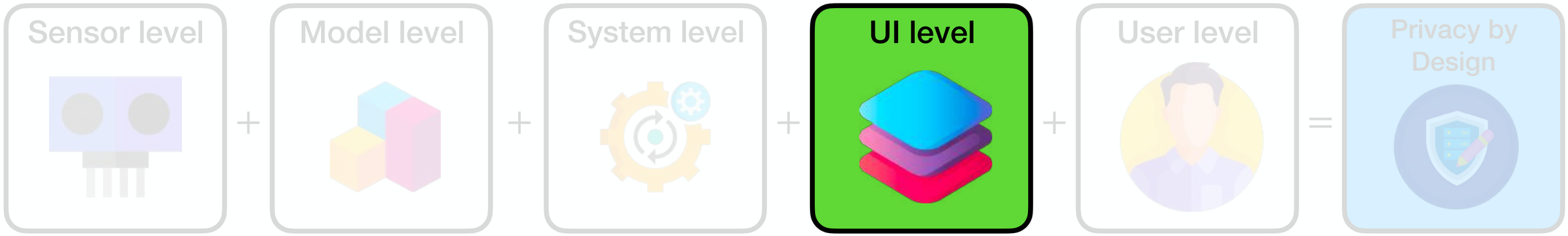
Cost-effective, low-maintenance.

Unobtrusive, cameras are ceiling mounted and out-of-view.

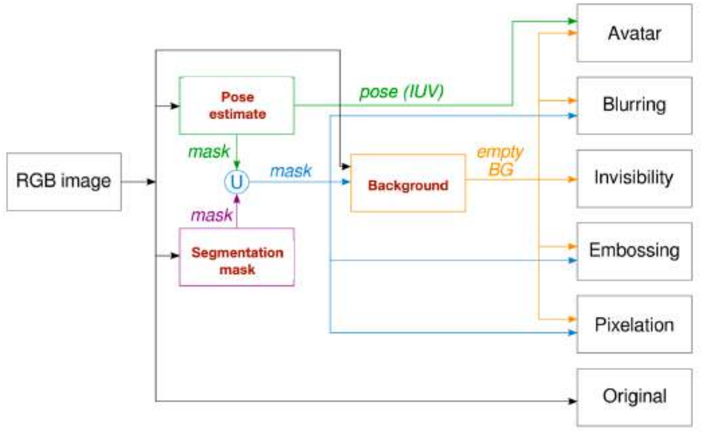
Robust to occlusions.


01/01/2015 03:00:59
DCS-6010L
Person standing, pouring water into glass
Unobtrusive camera placement
Entire scene seen In one frame

# Analysing design elements for visual Privacy by Design




Can we make it **applicable to omnidirectional images?**

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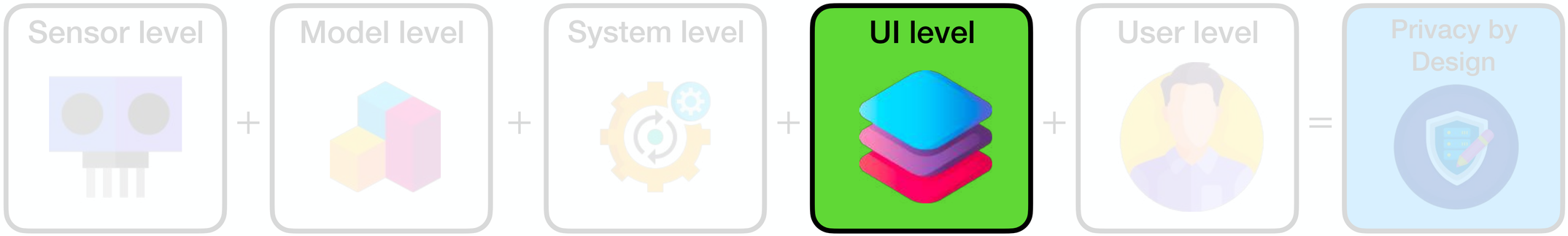


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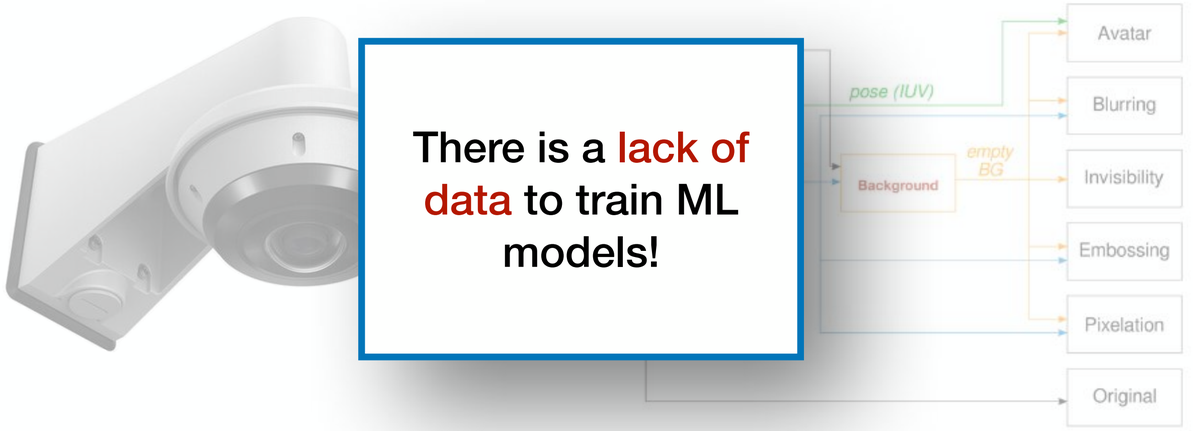

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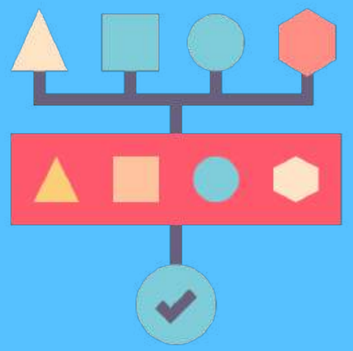

Yes, based on the review and pipeline.

**RQ2**

Can we provide privacy to individuals appearing in zenithal-view omnidirectional camera images?

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Can a private by design pipeline be created for omnidirectional images that adheres to legal regulations?

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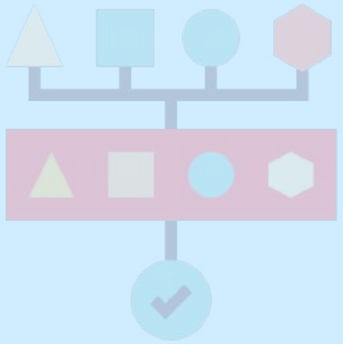

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# RQ2 Can we provide privacy to individuals appearing in zenithal-view omnidirectional camera images?

- Created ODIN, the first large-scale multi-modal omnidirectional dataset aimed at human behaviour and scene understanding.
- Recorded activities of daily living in real indoor environments which have varying levels of occlusion.
- Collaborative project with Trinity College Dublin.



**ODIN: An OmniDirectional INdoor dataset capturing Activities of Daily Living from multiple synchronized modalities**

Siddharth Ravi[1][0000-0002-2301-569X], Pau Climent-Perez[1], Théo Morales[2], Carlo Huesca-Spairani[1], Kooshan Hashemifard[1], Francisco Florez-Revuelta[1]

[1]University of Alicante [2]Trinity College Dublin

{siddharth.ravi, pau.climent, k.hashemifard, francisco.florez}@ua.es, moralest@tcd.ie, chs17@alu.ua.es

**Abstract**

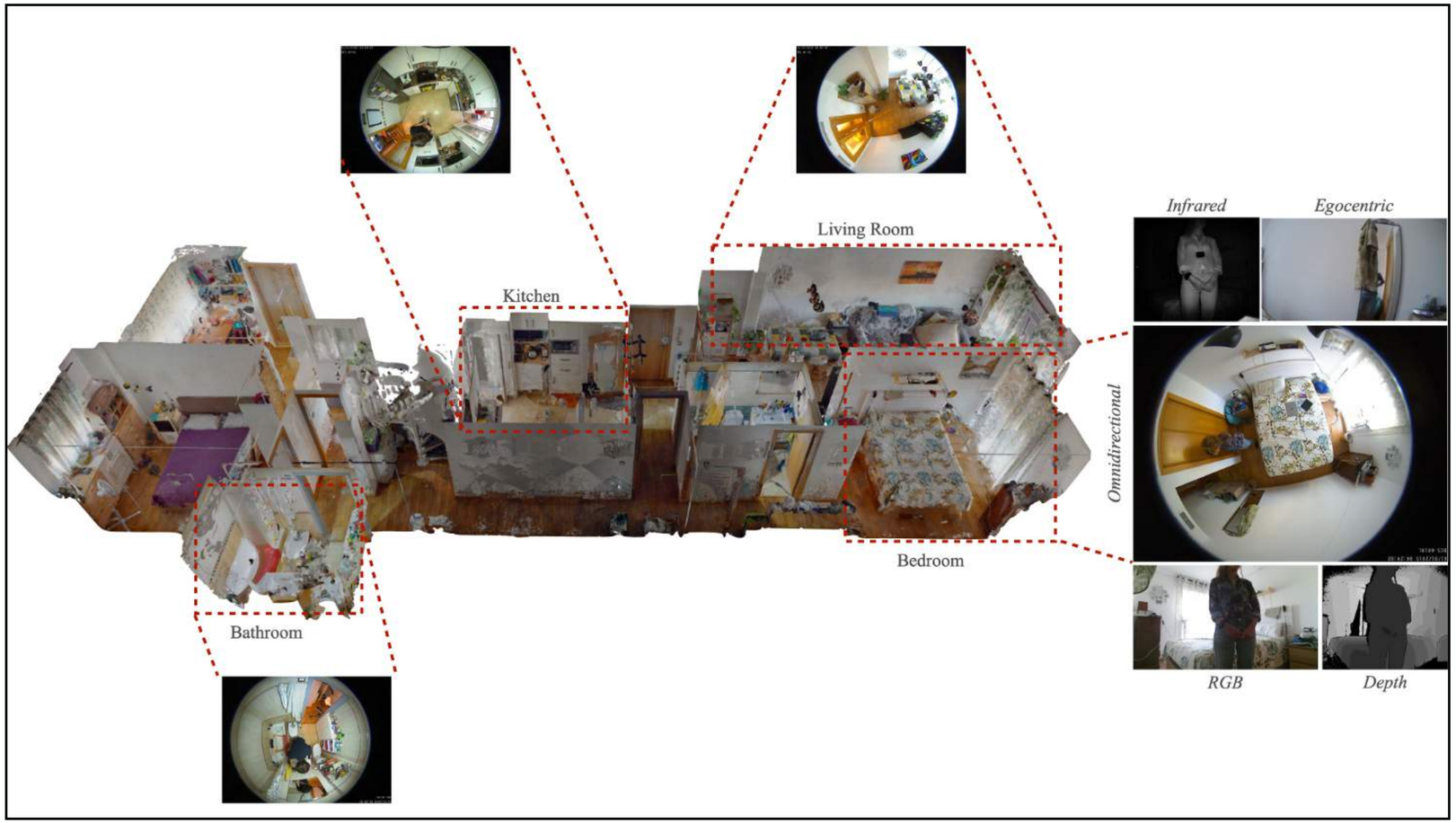
*We introduce ODIN (the OmniDirectional INdoor dataset), the first large-scale multi-modal dataset aimed at spurring research using top-view omnidirectional cameras in challenges related to human behaviour understanding. Recorded in real-life indoor environments with varying levels of occlusion, the dataset contains images of participants performing various activities of daily living. Along with omnidirectional images, additional synchronized modalities of data are provided. These include (1) RGB, infrared, and depth images from multiple RGB-D cameras, (2) egocentric videos, (3) physiological signals and accelerometer readings from a smart bracelet, and (4) 3D scans of the recording environments. To the best of our knowledge, ODIN is also the first dataset to provide camera-frame 3D human pose estimates for omnidirectional images, which are obtained using our novel pipeline. The project is open sourced and available at https://odin-dataset.github.io.*

thy solution to these problems. These cameras are generally unobtrusive, have a larger field of view, and can provide largely unoccluded views of the environments being monitored. However, HBU challenges such as pose estimation become all the more challenging due to the viewpoint and due to the heavy distortions introduced by the lens when compared to wide-angle lenses.

The aim of this work is to introduce a new large-scale omnidirectional dataset which contains numerous synchronized modalities. This includes images and videos from cameras of different types recording participants carrying out various activities of daily living, along with their physiological data. ODIN will support research in areas as varied as human pose estimation, activity recognition, person tracking and monitoring, scene understanding, privacy preservation, biometric monitoring, novel view synthesis, generative modelling, 3D scene reconstruction, and image registration. Through our first release, we aim to promote research on 3D human pose estimation using omnidirectional cameras. Research in this area is scarce, arguably due

*Source:* Ravi, S., Climent-Perez, P., Morales, T., Huesca-Spairani, C., Hashemifard, K., & Flórez-Revuelta, F. (2023). *ODIN: An OmniDirectional INdoor Dataset Capturing Activities of Daily Living From Multiple Synchronized Modalities*. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 6488–6497

# ODIN: An OmniDirectional INdoor Dataset




| Modality/characteristic | Amount |
|---|---|
| Omnidirectional RGB images | 332K |
| Lateral-view RGB images | 1.464M |
| Lateral-view infrared images | 1.464M |
| Lateral-view depth images | 1.453M |
| Environment meshes | 3 |
| Egocentric videos | 52 |
| Physiological readings | 39 |
| Accelerometer measurements | 39 |
| Participants | 15 |
| Locations | 4 |
| Types of environments | 5 |

*Source:* Ravi, S., Climent-Perez, P., Morales, T., Huesca-Spairani, C., Hashemifard, K., & Flórez-Revuelta, F. (2023). *ODIN: An OmniDirectional INdoor Dataset Capturing Activities of Daily Living From Multiple Synchronized Modalities*. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 6488–6497

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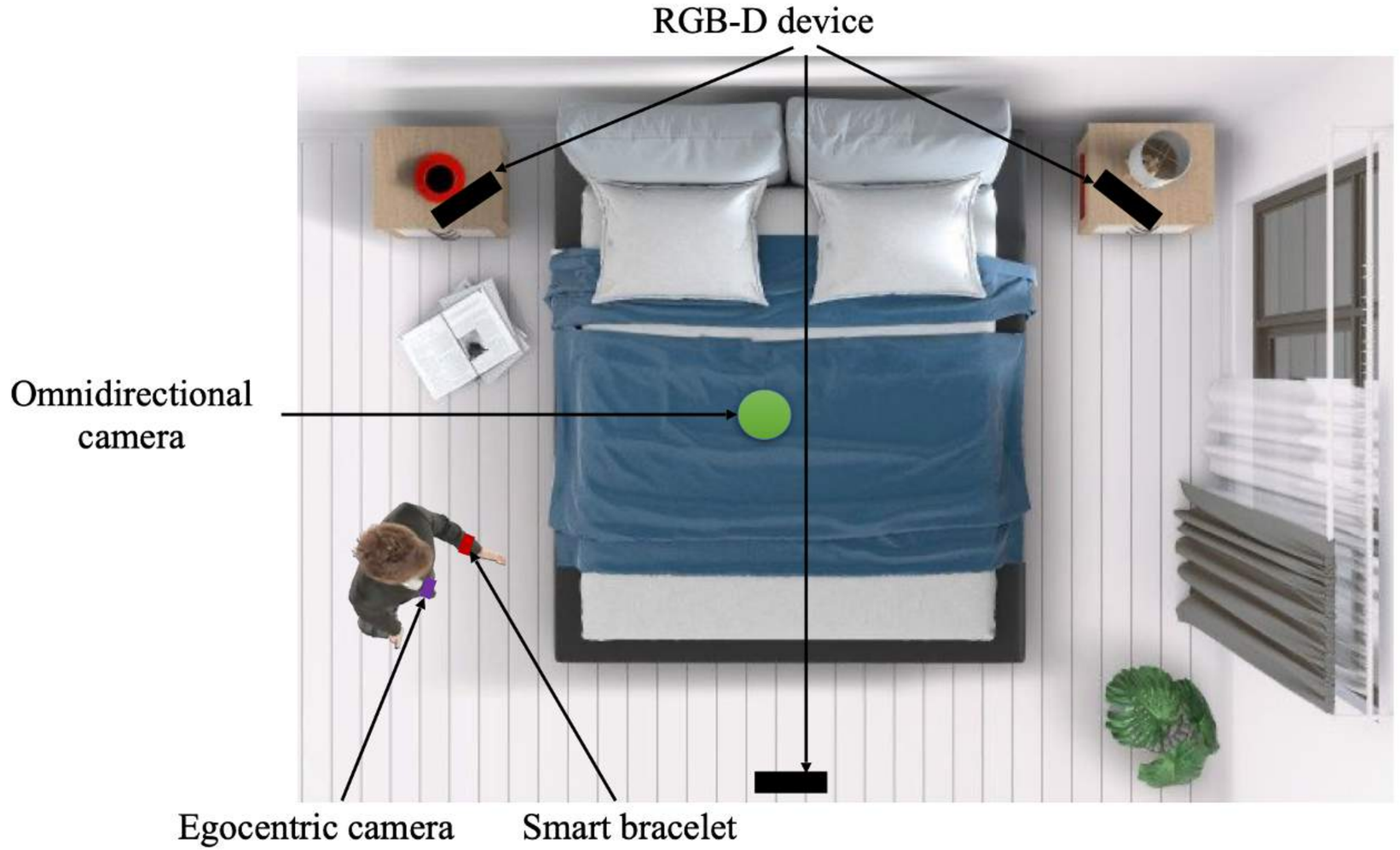


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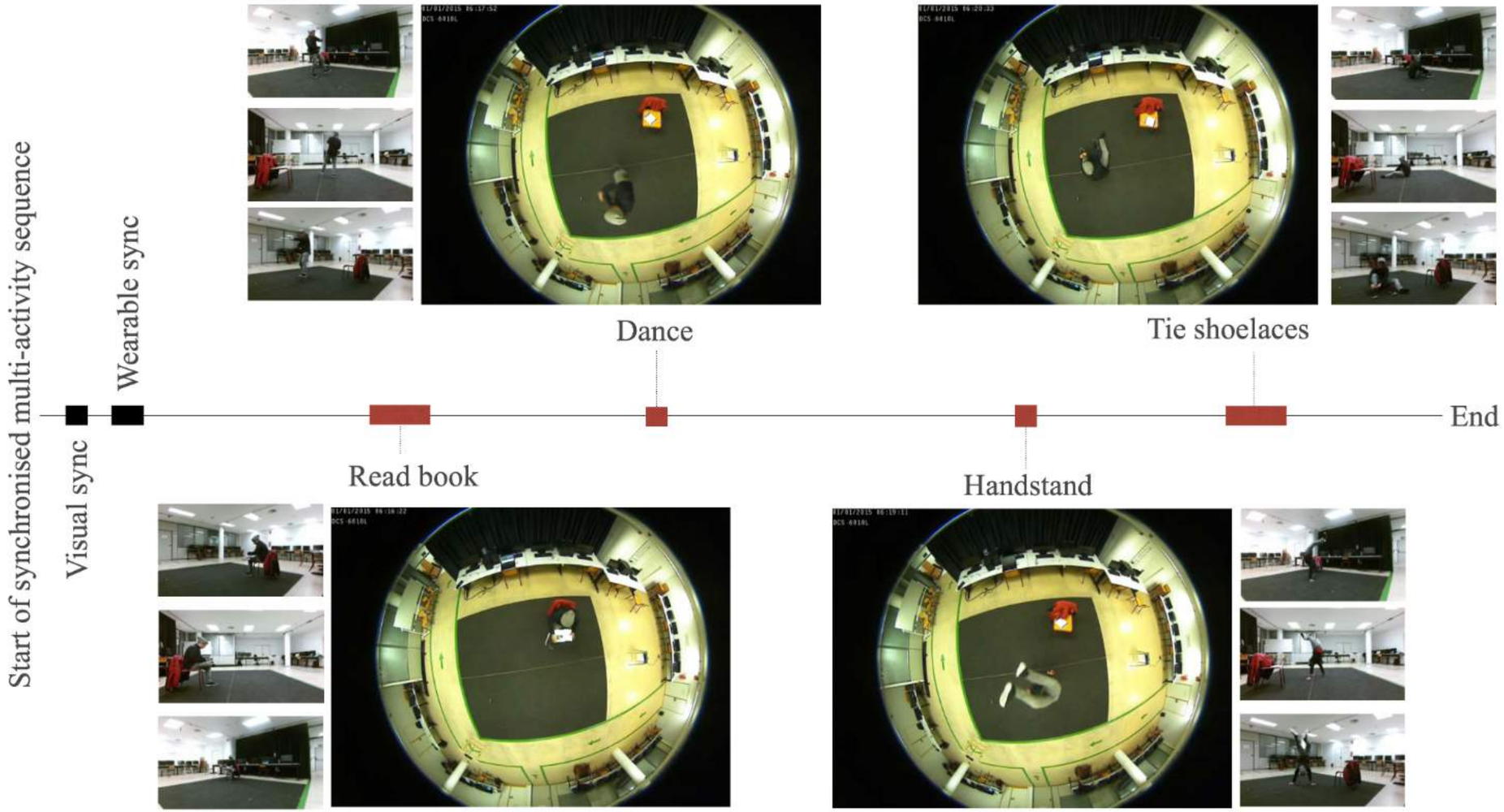


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# ODIN: An OmniDirectional INdoor Dataset

| Dataset | Omni | Ego | RGB | 3D scans | Stereo | IMU | Synced-cam | Phys. signals | Pose | Activity labels | Audio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **ODIN** | ✓ | ✓ | ✓ | ✓ | ✓ | (Partial) | ✓ | ✓ | ✓ | (×) | × |
| PIROPO Database | ✓ | × | × | × | × | × | ✓ | × | × | ✓ | × |
| WEPDTOF | ✓ | × | × | × | × | × | × | × | × | × | × |
| Fisheye dataset | ✓ | × | × | × | × | × | × | × | × | × | × |
| MPII Human Pose | × | × | ✓ | × | × | × | × | × | ✓ | × | × |
| Human3.6M | × | × | ✓ | × | × | × | ✓ | × | ✓ | × | × |
| Toyota Smarthome | × | × | ✓ | × | ✓ | × | ✓ | × | ✓ | ✓ | × |
| NTU RGB+D Dataset | × | × | ✓ | × | ✓ | × | ✓ | × | ✓ | ✓ | × |
| ADL Dataset | × | × | ✓ | × | × | × | × | × | × | ✓ | × |
| EPIC KITCHENS \| | × | ✓ | × | × | × | × | × | × | × | ✓ | × |
| Ego4D | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | × | ✓ | ✓ |

- All modalities are synchronised, static cameras are all calibrated for perspective projection.
- Made to be used for tasks as varied as activity recognition, person tracking and monitoring, scene understanding, biometric monitoring, novel view synthesis, generative modelling, 3D scene reconstruction, and image registration.
- First version of ODIN aimed at omnidirectional 3D human pose estimation.

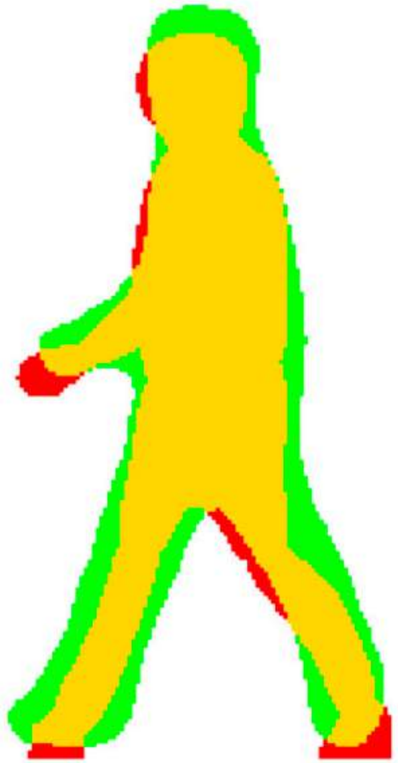
*Source:* Ravi, S., Climent-Perez, P., Morales, T., Huesca-Spairani, C., Hashemifard, K., & Flórez-Revuelta, F. (2023). *ODIN: An OmniDirectional INdoor Dataset Capturing Activities of Daily Living From Multiple Synchronized Modalities*. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 6488–6497

# Refining omnidirectional pose estimates

## Ongoing work

- Currently working on refining the human pose estimates.
- Multiple improvements to version 1 of the dataset were created in the process - Open-source contributions to a SOTA lateral-view pose estimation model setup, more accurate calibration matrices, better synchronization between frames, activity labels etc.

# Next Steps



- Refining the pose estimates for omnidirectional images.
- Retraining a popular pose estimation model through the obtained poses for omnidirectional pose estimation.
- Manipulating the estimated meshes to become semantic segmentation masks, and retraining popular semantic segmentation models.
- Plugging these models into the pipeline from Climent-Perez and Florez-Revuelta (2021).

Source: Climent-Pérez, P., & Florez-Revuelta, F. (2021). Protection of visual privacy in videos acquired with RGB cameras for active and assisted living applications. *Multimedia Tools and Applications*, *80*(15), 23649–23664.

# Research Questions

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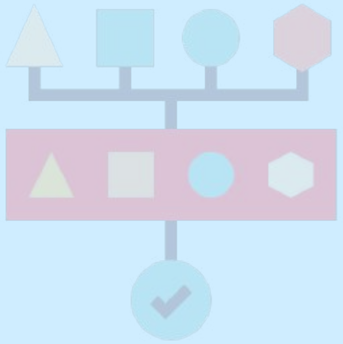

**RQ2**

Can we provide privacy to individuals appearing in zenithal-view omnidirectional camera images?

Work ongoing, closing towards a ‘yes’

**RQ3**

Can a private by design pipeline be created for omnidirectional images that adheres to legal regulations?

# Research Questions

RQ1

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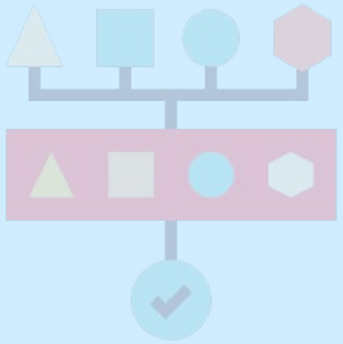


RQ2

Can we provide privacy to individuals appearing in zenithal-view omnidirectional camera images?

RQ3

**Can a private by design pipeline be created for omnidirectional images that adheres to legal regulations?**

**RQ3** Can a private by design pipeline be created for omnidirectional images that adheres to legal regulations?

What are the relevant **legal regulations** to inspect?


How do we get close to **privacy by design**?

# What does the legal literature say about PETs?

**Relevant points**

- Anonymisation: Irreversible de-identification of data
- Pseudonymisation: Reversible de-identification of data
- Data Protection by Design: Privacy ought to be integrated into systems from the start
- Most PETs can be considered pseudonymisation due to technical reversibility.

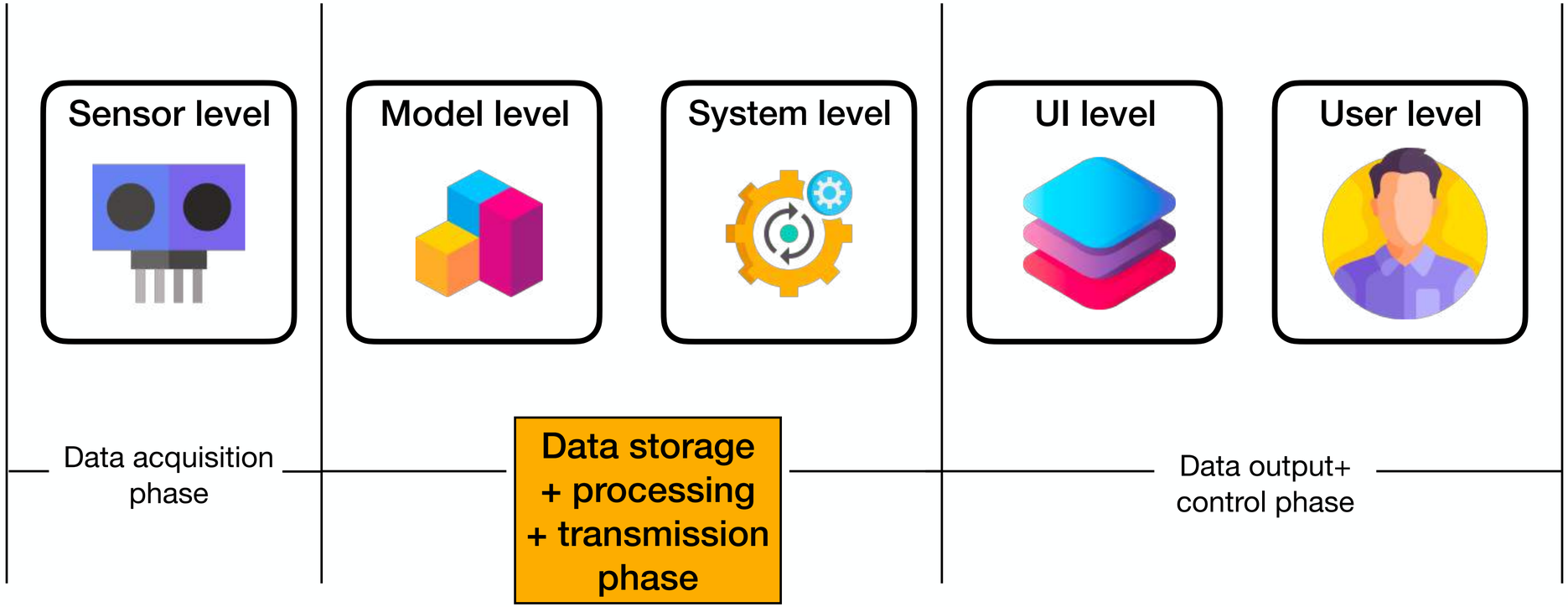
| Takeaways | |
|---|---|
| | 1. There is a need for concrete guidelines on what constitutes privacy by design under EU data protection laws. |
| | 2. There are multiple guidelines which one can follow to get closer to the goal. |
| | 3. The proposed EU AI act is a step in the right direction. |
| | 4. Mihailidis and Colonna (2020) still pave the way forward. |

*Source:* He, Z. (2022). Privacy-enhancing Technologies for Active and Assisted Living: What Does the GDPR Say? *Proceedings of the 15th International Conference on PErvasive Technologies Related to Assistive Environments*, 430–433.
Mihaildis, A., & Colonna, L. (2020). A Methodological Approach to Privacy by Design within the Context of Lifelogging Technologies. *Rutgers Computer and Technology Law Journal, 46, 1.*

# Creating and analysing an end-to-end PbD system


- Secondment completed in Stockholm (May-July ’23)
- Investigated system design elements to create an end-to-end private by design pipeline.
- Did a study of the legal scholarship pertaining to the system’s design.
- As part of the AI act proposal of April 2021, the system can be considered as high-risk.

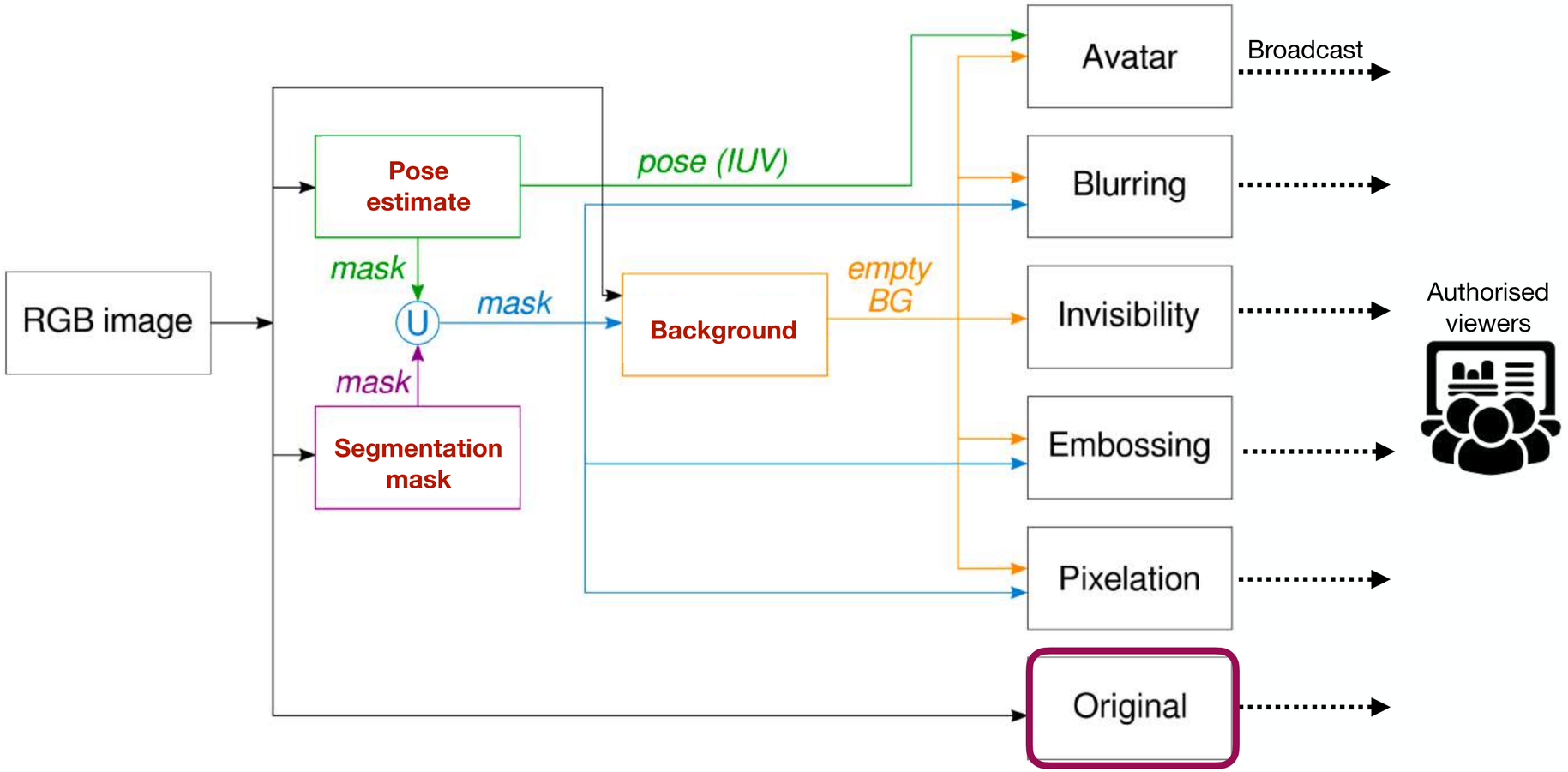
# Creating and analysing an end-to-end PbD system




- Investigated the feasibility of using steganography and encryption schemes to safely transmit and store data from within the pipeline.
- Both have advantages and disadvantages, but encryption schemes were deemed more suitable for our use-case.
- Schemes were investigated under the idea that data can be hidden in the system that allows to reconstruct the original if necessary, and for the model / system level phases of the pipeline.

Source: Mihaildis, A., & Colonna, L. (2020). A Methodological Approach to Privacy by Design within the Context of Lifelogging Technologies. *Rutgers Computer and Technology Law Journal, 46, 1.*

# Pipeline for privacy preservation

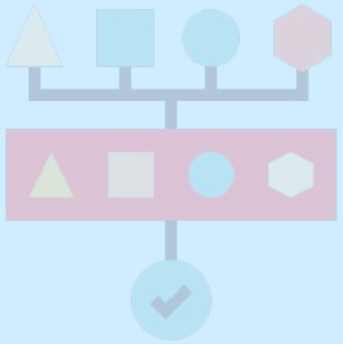



Source: Climent-Pérez, P., & Florez-Revuelta, F. (2021). Protection of visual privacy in videos acquired with RGB cameras for active and assisted living applications. *Multimedia Tools and Applications*, *80*(15), 23649–23664.

# Research Questions

RQ1

Can we provide contextual visual privacy for individuals appearing in images?



RQ2

Can we provide privacy to individuals appearing in zenithal-view omnidirectional camera images?

RQ3

Can a private by design pipeline be created for omnidirectional images that adheres to legal regulations?

Yes, design elements were investigated and legal literature was consulted.

# Timeline

| Activity\Month | | | November | December | | | | January | | | | February | | | | March | | | | April | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 |
| Dataset | Annotation | Correct pose estimation pipeline | | | | | | | | | | | | | | | | | | | | |
| | ML Modeling | Model training - Baseline pose estimation from top (pipeline + training) | | | | | | | | | | | | | | | | | | | | |
| | | Model training - semantic segmentation from the top | | | | | | | | | | | | | | | | | | | | |
| | Miscellaneous Tasks | Thesis writing | | | | | | | | | | | | | | | | | | | | |

# Dissemination Overview

Journal / Conference / Workshop papers:

1. **S Ravi**, P Climent-Pérez, F Florez-Revuelta. (2023). A review on visual privacy preservation techniques for active and assisted living, Multimedia Tools and Applications. pp. 1-41

2. **S Ravi**, P Climent-Pérez, T Morales, C Huesca-Spairani, K Hashemifard, F Florez-Revuelta. (2023). ODIN: An OmniDirectional INdoor Dataset Capturing Activities of Daily Living From Multiple Synchronized Modalities. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, pp. 6488-6497,

Collaborative works:

1. S Noiret, **S Ravi**, M Kampel, F Florez-Revuelta. (2022). On The Nature of Misidentification With Privacy Preserving Algorithms. Proceedings of the 15th International Conference on PErvasive Technologies.

2. S Noiret, **S Ravi**, M Kampel, F Florez-Revuelta. (2023). Fairly Private: Investigating The Fairness of Visual Privacy Preservation Algorithms, Presented at the Privacy preserving AI workshop at AAAI ´23. arXiv preprint arXiv:2301.05012

Position Papers:

1. S Aleksic, et al., (2022). State of the art in privacy preservation in video data

2. A Klimczuk et al., (2022). Position Paper on Ethical, Legal and Social Challenges Linked to Audio-and Video-Based AAL Solutions.

# Future Career Ambitions

- Would like to continue in computer vision / ML research after finishing PhD.
- Open to both industry and academic opportunities.
- Would like to lead research teams in the future and keep furthering science.

# Feedback about VisuAAL

- By far the hardest thing I've ever done.
- Helped me get exposure to different schools of thought.
- First truly interdisciplinary project.
- Learned a lot, gained some fun memories, and met some great people along the way.

visuAAL

Privacy-Aware and Acceptable Video-Based Technologies and Services for Active and Assisted Living

# Thank you!

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