S.A.V.E.

Seamless Augmented Vision Equipment

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EPFL

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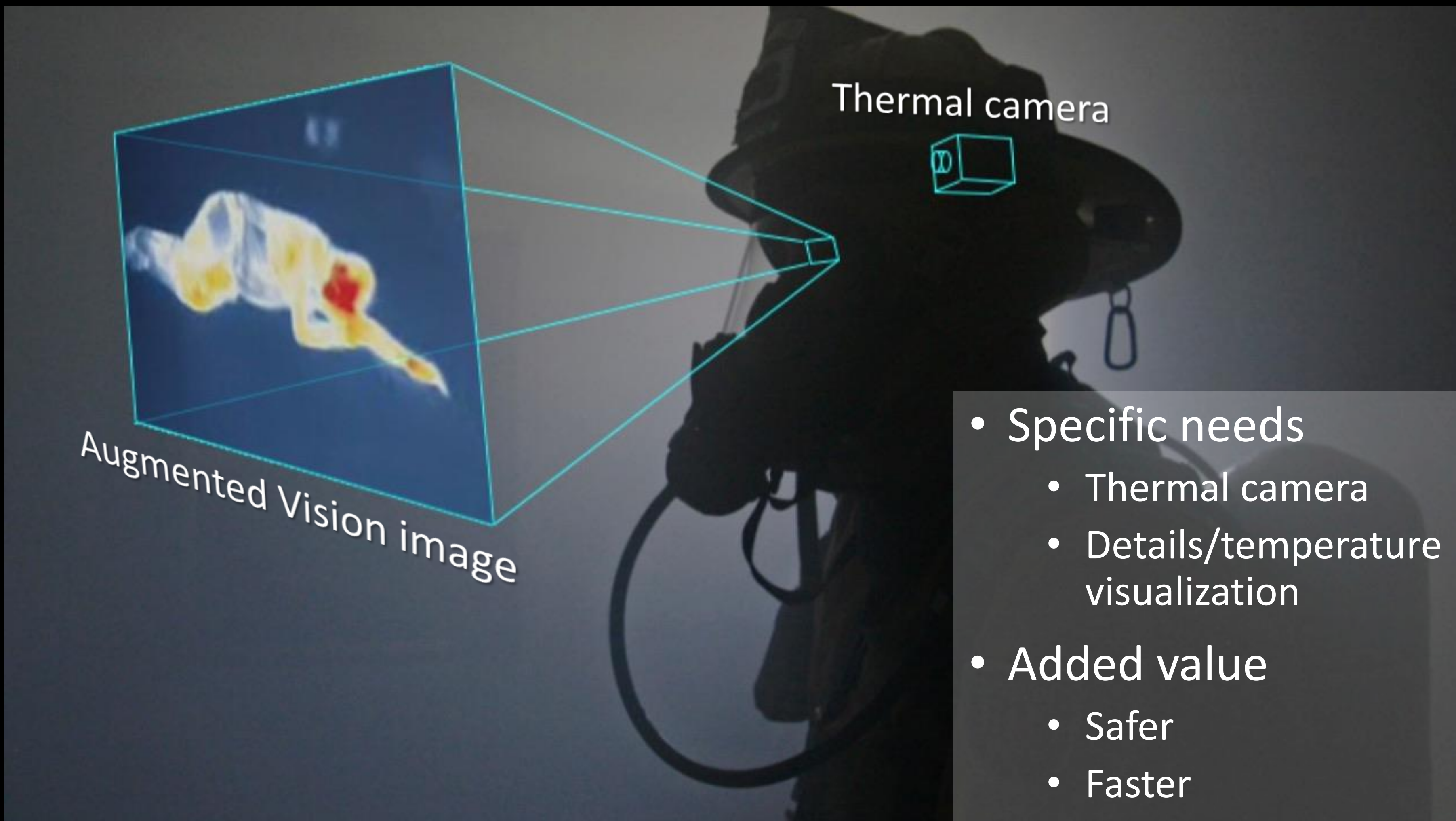
Contributions

Models and methods for ***enhancing human vision*** through the use of ***multiple sensor*** sources, fused and calibrated to optimize the ***seamless perception*** of information in ***critical applications***.

Firefighting: Thermal + Visible Sources

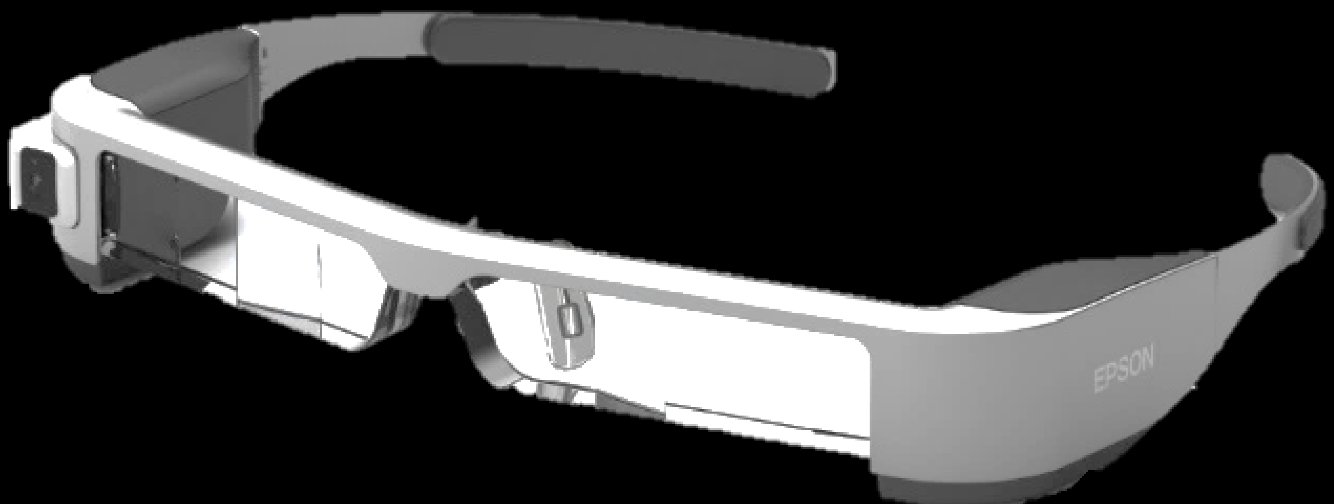


- Specific needs
  - Thermal camera
  - Details/temperature visualization
- Added value
  - Safer
  - Faster

Outline

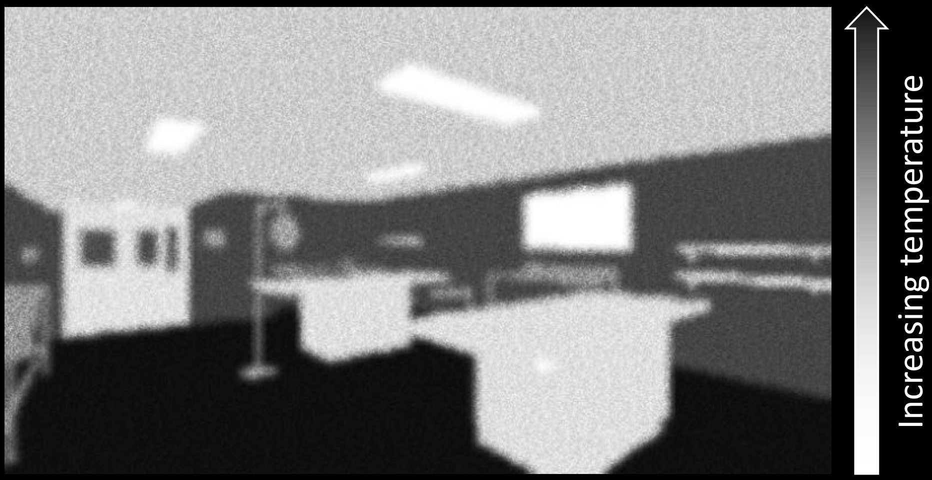
- Display Calibration and Image Fusion
- Sensing Platform
- User Perception
- Outlook
- Demo

Augmented Vision (AV) equipment



- Optical See-Through Head-Mounted Displays (OST HMD)
- Projects a virtual image onto a transparent screen, allowing users to see through it.

AV in VR: Simulating augmented reality glass for image fusion



- Assign temperatures to objects ranging from 0 to 1
- Thermal Shader replaces camera's shader to obtain the thermal image

F.Lahoud and S. Süsstrunk, **AR in VR: Simulating Infrared Augmented Vision**. *25th IEEE International Conference on Image Processing (ICIP), 2018*.

Image Fusion

Spectral Compression

$$R_i' = \frac{3I_i + R_i}{4} \quad G_i' = \frac{G_i + R_i}{2} \quad B_i' = \frac{3B_i + G_i}{4}$$

Binary Blending

$$RGB_i' = \begin{cases} (1-\alpha)RGB_i + \alpha I_i, & \text{if } intensity(RGB_i) >= \beta \\ \alpha I_i, & \text{otherwise} \end{cases}$$

Inverse

$$RGB_i' = avg_i RGB_i + (1 - avg_i) I_i$$

Noise Modulation

$$RGB_i' = RGB_i + 0.5 I_i * rand(0,1)$$

Adaptive Blending

$$RGB_i' = \begin{cases} \frac{RGB_i}{RGB_i + I_i} RGB_i + \frac{I_i}{RGB_i + I_i} I_i, & \text{if } intensity(RGB_i) >= \beta \\ \frac{I_i}{RGB_i + I_i} I_i, & \text{otherwise} \end{cases}$$

Inverse Square

$$RGB_i' = avg_i^2 RGB_i + (1 - avg_i)^2 I_i$$

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Visibility Conditions

No light

Low light

Cold smoke

Normal light

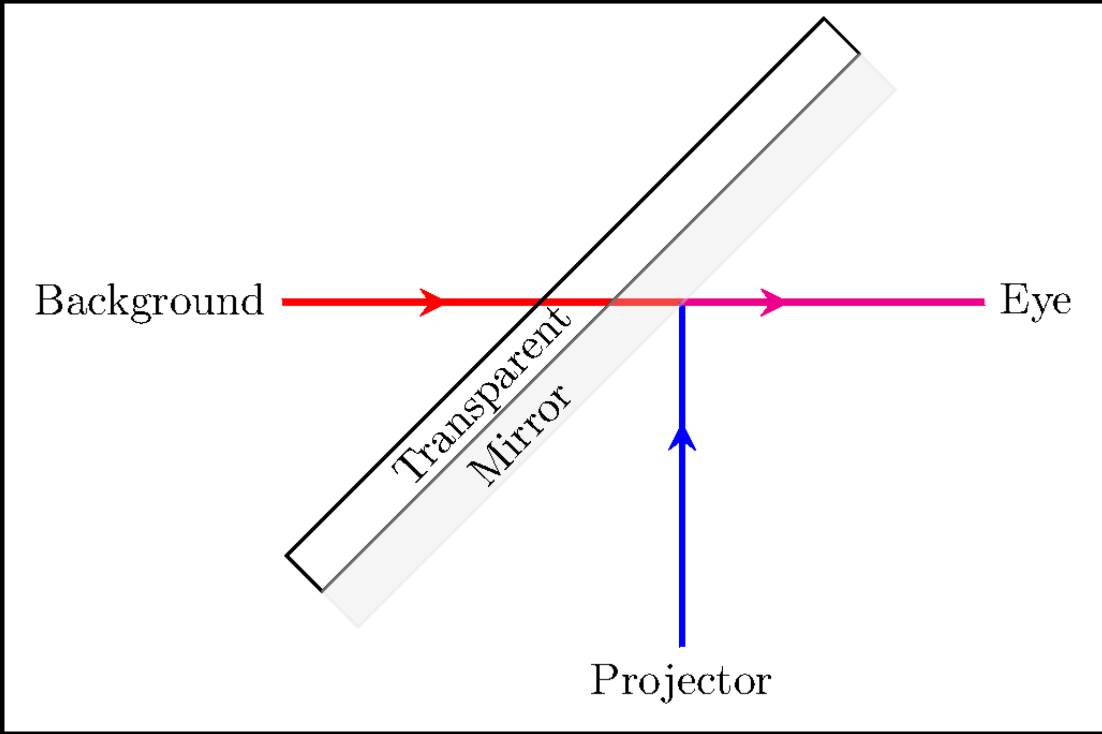
Bright light

Hot smoke

Accurate AV Display Model

Calibrate for:

- Refraction
- Transmission
- Dispersion
- Intensity of projector
- Reflectivity of glass
- Ghost Images

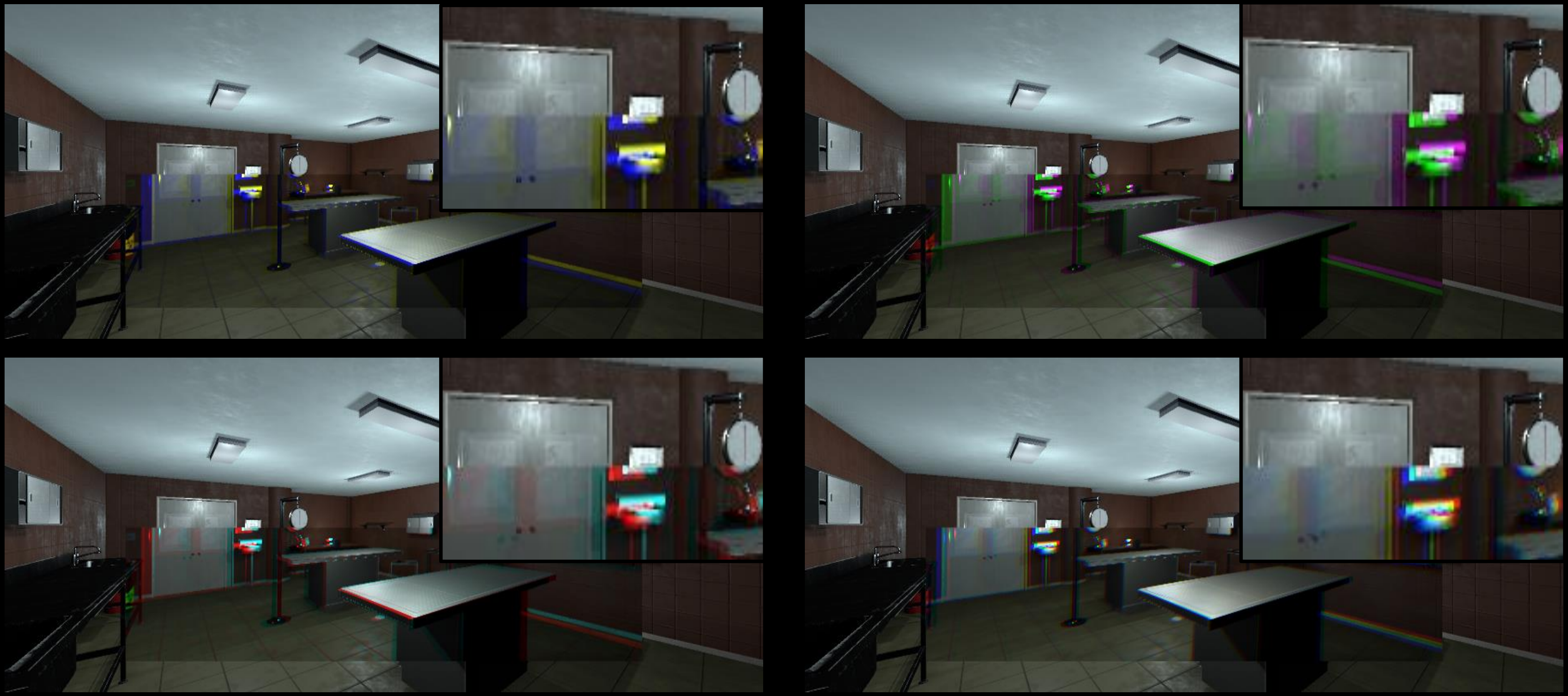


F.Lahoud and S. Süsstrunk, **AR in VR: Simulating augmented reality glass for image fusion**. IS&T International Symposium on Electronic Imaging, 2019.


Refraction: screen alone


Refraction: screen with AV projection

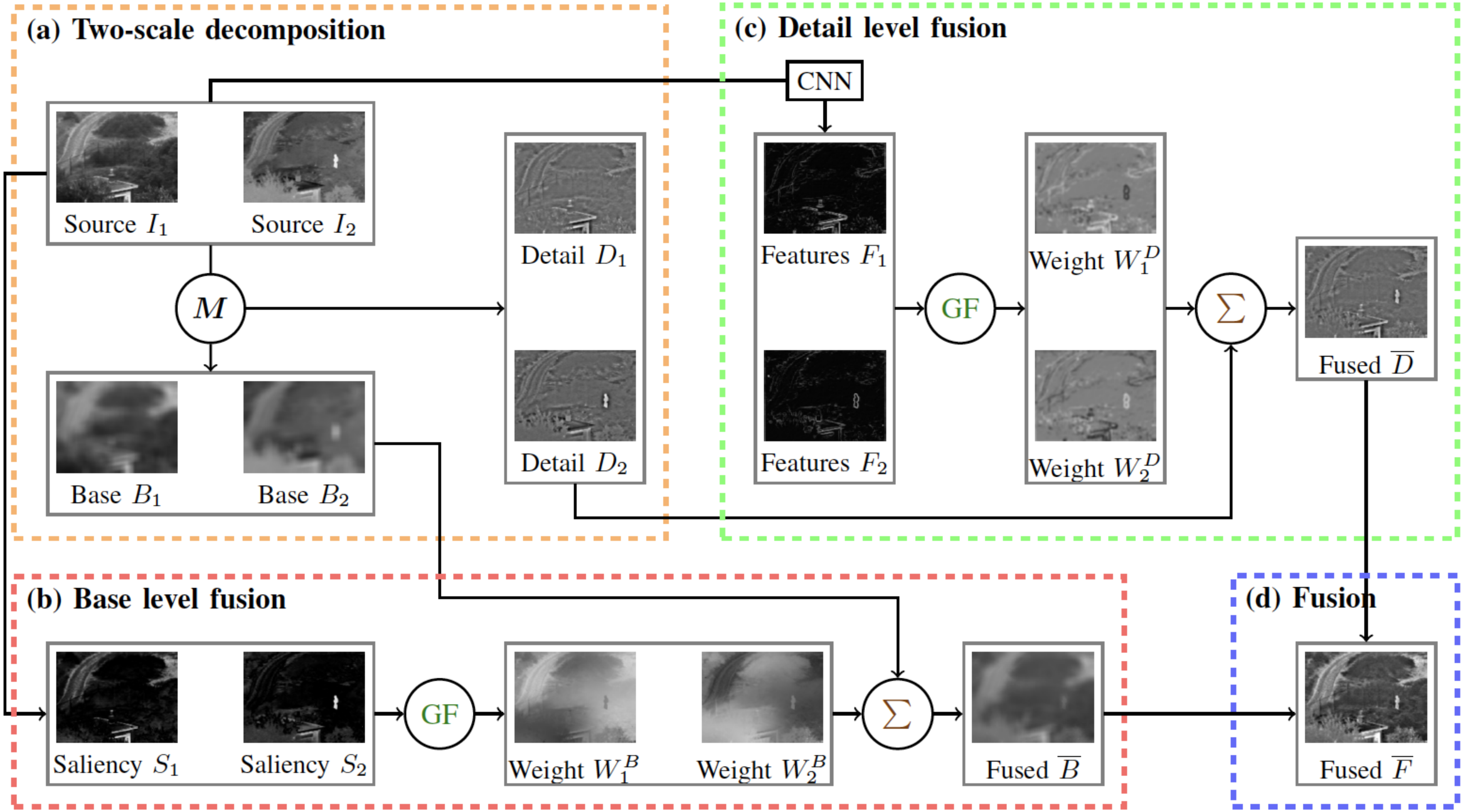
Dispersion




Before


After

Zero-Learning Image Fusion



F.Lahoud and S. Süsstrunk, **Fast and Efficient Zero-Learning Image Fusion**. Submitted to IEEE Transactions on Image Processing, 2019.

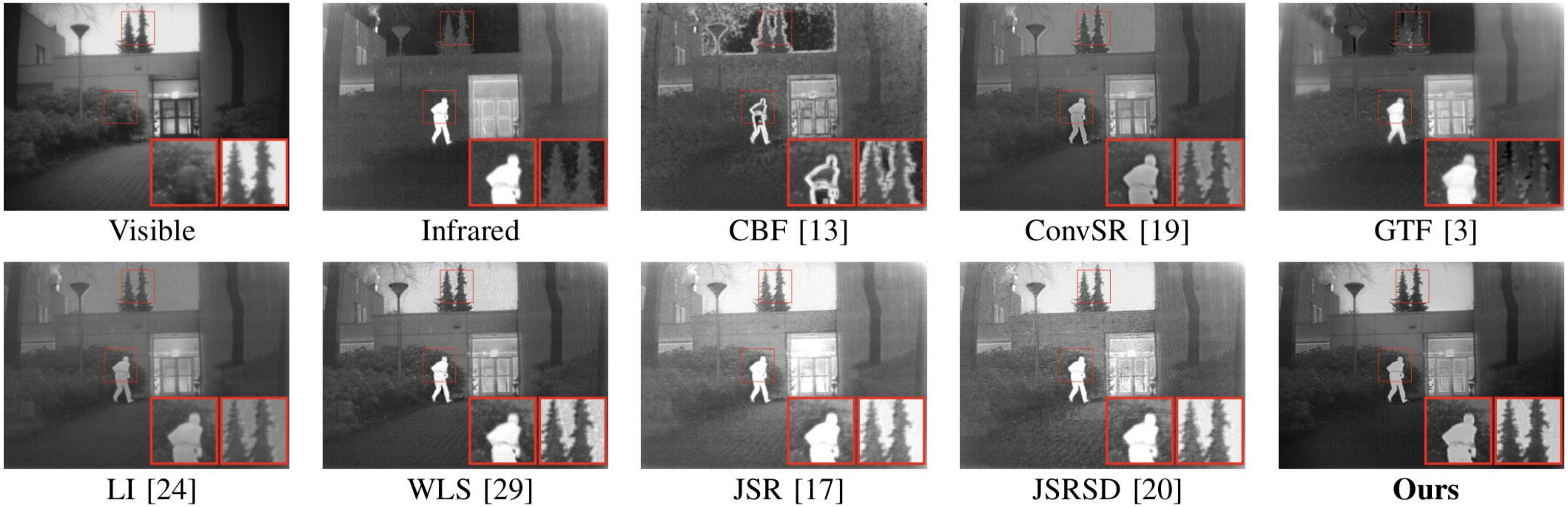


TABLE II

OBJECTIVE ASSESSMENT OF DIFFERENT METHODS ON INFRARED AND VISIBLE IMAGE FUSION. **BOLD** AND UNDERLINED VALUES INDICATE THE **BEST** AND SECOND-BEST SCORES, RESPECTIVELY. TIME WAS COMPUTED ON IMAGES WITH AN AVERAGE SIZE OF 460×610 ($\pm 115 \times 155$).

Metric	CBF [13]	ConvSR [19]	GTF [3]	LI [24]	WLS [29]	JSR [17]	JSRSD [20]	Ours
EN	6.857	6.259	6.635	6.182	6.638	6.363	6.693	**7.126**
MI	13.714	12.517	13.271	12.364	13.276	12.727	13.386	**14.252**
VIFF	0.265	0.272	0.188	0.259	0.444	0.363	0.292	**0.690**
Q_{MI}	2.039	1.946	2.006	1.934	2.006	1.963	2.014	**2.064**
Q_G	0.378	0.491	0.421	0.364	**0.509**	0.308	0.265	0.500
Q_Y	0.643	0.802	0.726	0.702	0.805	0.588	0.501	**0.816**
Q_C	0.486	0.594	0.468	0.606	0.601	0.467	0.427	**0.649**
Q_P	0.147	**0.355**	0.205	0.297	0.309	0.173	0.118	0.315
Time	15.28	86.8	2.57	6.20	1.28	346.18	396.74	**0.16**
Std σ	6.69	37.44	1.31	2.79	0.65	151.25	178.73	**0.08**

F.Lahoud and S. Süsstrunk, **Fast and Efficient Zero-Learning Image Fusion**. Submitted to IEEE Transactions on Image Processing, 2019.

Video Fusion


0:18:38


0:18:38

Sensing Platform

IR camera
& visible camera

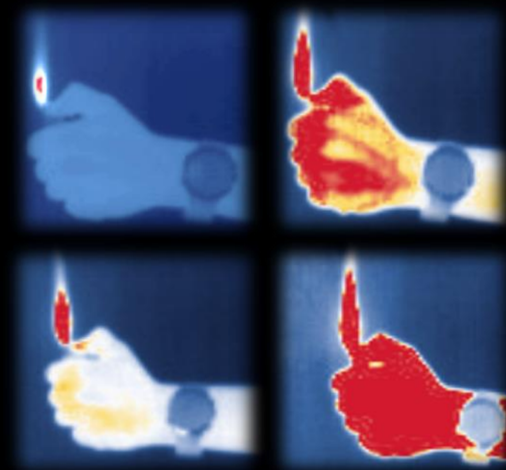
Light sensor

Augmented reality
glasses

Additional
IR camera

Sensing Platform

- Development regarding the needs for the user tests
  - Recording capability (Visible & IR)
  - Flexible, polyvalent
  - Thermal coloring / dynamic



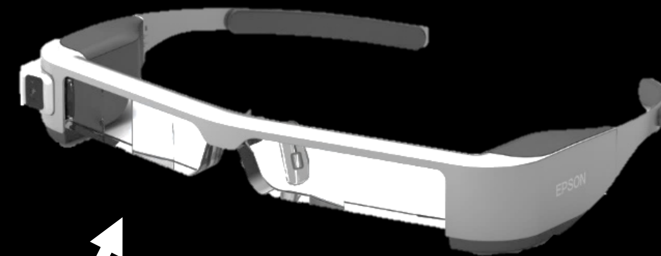
- Advanced features
  - CNN based Pedestrian detection (IR)
  - Integrated solution

Sensing Platform

Additional sensors

IR camera

Embedded processing platform



Augmented reality glasses

Control box

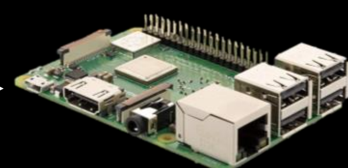
- Color scale, dynamic
- Monocular / binocular
- Adjustment
- Switch on/off detection

Sensing Platform

Embedded processing platform

Initial modular platform

FLIR Lepton, Boson, TAU
Visible camera
Light sensor
Gigabit Ethernet interface



Raspberry Pi

More portable
→ User tests

Nvidia Jetson Xavier

More processing power
→ Demonstration
(pedestrian detection)

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User Perception

- *What are the models and validation procedures used for measuring the stress and the cognitive charge? What are their effects on user performances and inter-user differences?*
- *What should be adapted for each application scenarios and users in order to have the most seamless augmented vision?*

State of the art – Seamlessness in AR

- Augmented Reality impact on human perception
- Aspects participating to seamless vision (mismatch between real/virtual content, dual viewing, etc)
- Laboratory conditions
- No integration of contextual and user aspects
- No evaluation of visual comfort and global performance

An activity-centered approach

Seamlessness → Comfort Perception → **Activity optimisation**

Importance to understand **real activity** with current thermal cameras

Important criterias in activity

- **Characteristic Action Situations** (SAC)
- **Dimensions to evaluate** participating in **physical and cognitive comfort**

→ **Seamlessness**

Methodology

- Current firefighting activity
  - Real activity observations
  - Theoretical instructions
  - Thermal use simulation
- Tests in experimental conditions
  - Boiler room, HE-Arc
- Tests in realistic conditions
  - Military training site

→ Models for human perception

Current firefighting activity

- Theoretical use of thermal camera:
  - Recognition > Extinction > Rescue
  - Save time during progression
  - *«The thermal camera is our **life line**»*
- Dimensions of real activity :
  - Visual information (thermal and natural)
  - Gesture and posture
  - Communication
  - Somesthetic indicators

  → Protect themselves

→Identify performance criteria of the activity

→Identify Characteristic Actions Situations

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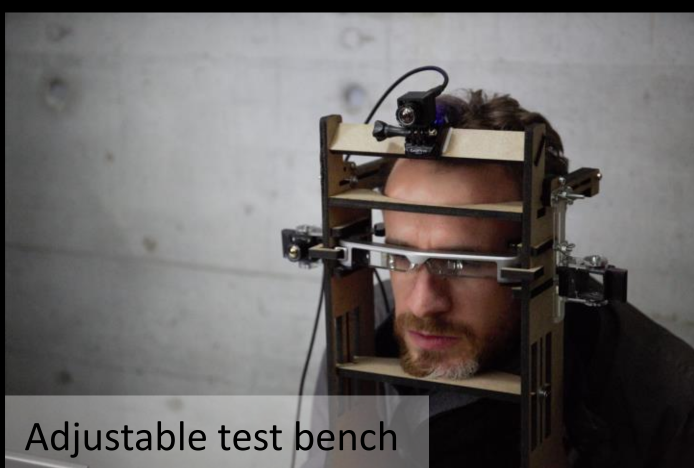
Tests in experimental conditions

- Test of 4 different AR configurations on a static bench
- Objective: Identify the most performant configuration regarding firefighting activity
- Characteristical action situation: find a hotspot in a complex environment, objects at different depths and heights, obstacles, narrow accesses, etc.
- Environmental conditions: half and full darkness



Adjustable test bench

Complex and unknown environment

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Tests in realistic conditions

- Dynamic test with an embedded SAVE system
- 3 environmental conditions: outdoor by day/ indoor in full obscurity/ indoor in smoke
- Task : Identify a hot spot in a complex and unknown environment
- Evaluate the seamlessness and performance of the system

Embedded system with new functionalites

Realistic environnemental conditions

Observables and data collection

- Observables:
  - **Global performance**
  - **Moving strategies**
  - **Visual comfort**
  - **Physical and cognitive loads**
- Focus on qualitative data :
  - Think-aloud method and questionnaires
  - Thermal and visible videos
  - Settings and chronos
- Quantitative data abandoned, cause of bias
- Existing tools for stress level and cognitive charge too generic and therapeutically oriented

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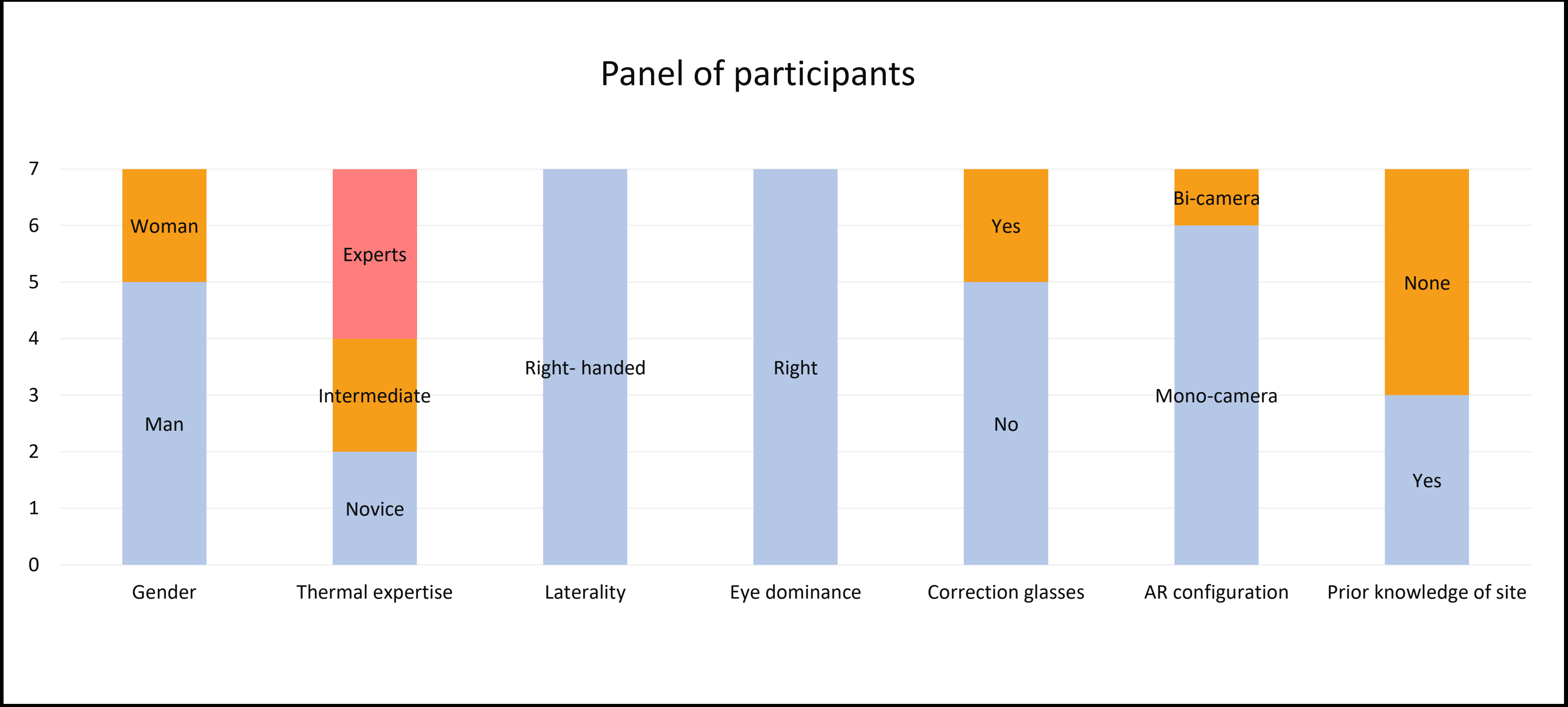
First Results

- 7 participants
- Different thermal background: Experts, intermediate and novice



Algorithms for user perception (In progress)

Phase during activity	Cognitive process	Seamless vision
Exploration	• Scan a large area without forget hidden recesses • Identify hot spots and T°	• Large camera FOV (90°) • Thermal modes and color rendering
Progression	• Evaluate distances and avoid obstacles • Identify objects contours	• Narrow FOV ~60°, centered camera • Image quality (320-256px)
Extinction	…	…

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Outlook

- Image fusion to video fusion.
- Integration of the display model calibration and fusion algorithm on the embedded platform.
- More embedded solution – miniaturization, real-time.
- Validation of procedures/models to measure stress and cognitive load.

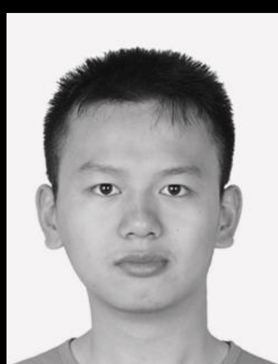
Team Members


Carole Baudin


Louis Delabays


Hakki Karaimer


Fayez Lahoud


Chen Liu


Laura Maillard


Nuria Pazos Escudero


Sabine Süsstrunk

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Papers and Presentations

- C. Baudin, and L. Maillard. **Outils méthodologiques pour l'évaluation de la réalité augmentée en environnement complexe.** ARPEGE Research Commission on AR, VR, MR, November 2019
- C. Baudin, and L. Maillard. **Impact de la réalité augmentée sur l'activité dans des environnements complexes.** Activités, April 2020
- F. Lahoud and S. Süsstrunk, **AR in VR: Simulating Infrared Augmented Vision.** In IEEE International Conference on Image Processing (ICIP), 2018.
- F. Lahoud, R. Zhou and S. Süsstrunk, **Multi-Modal Spectral Image Super-Resolution**, in Proceedings of the European Conference on Computer Vision (ECCV) Workshops, 2018.
- F. Lahoud and S. Süsstrunk. **AR in VR: Simulating augmented reality glass for image fusion**. IS&T International Symposium on Electronic Imaging, 2019.
- Fayez Lahoud, Radhakrishna Achanta, Pablo Márquez-Neila, Sabine Süsstrunk**. Self-Binarizing Networks**, arXiv:1902.00730 .
- F. Lahoud and S. Süsstrunk. **Zero-Learning Fast Medical Image Fusion**. In 22nd International Conference on Information Fusion (FUSION 2019), 2019.
- F. Lahoud and S. Süsstrunk. **Fast and Efficient Zero-Learning Image Fusion**. Submitted to IEEE Transactions on Image Processing, 2019.

Demo

1. Color scale
2. Zoom + adjustment
3. Pedestrian detection