Detection Considerations for Thermal Imaging

Centre for Mechatronics and Hybrid Technology
Mechanical Engineering - McMaster University
Ben Miethig

EECOMOBILITY (ORF) & HEVPD&D CREATE

SAVING LIVES – AUTONOMOUS DRIVING

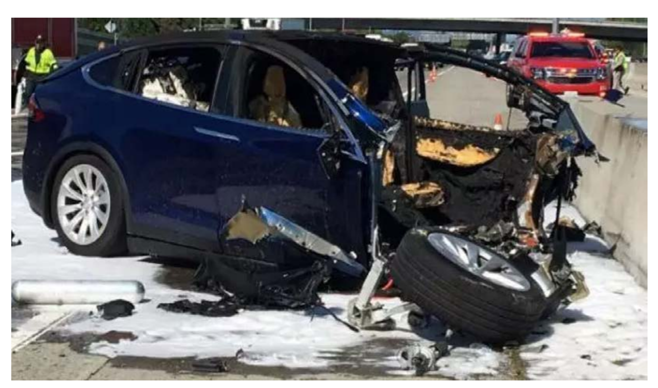
Goal of autonomous driving: A vehicle is able to drive to a final destination without endangering its surroundings (ie. **pedestrians**) or its occupants.

Requirements for safe driving:
100% detection of the vehicle's surrounding people and animals coupled with appropriate driving responses to these surroundings

- Requires fusion of multiple sensors that supply a variety of information. Typical sensors include CCD cameras, radars, LIDARs, and ultrasonic

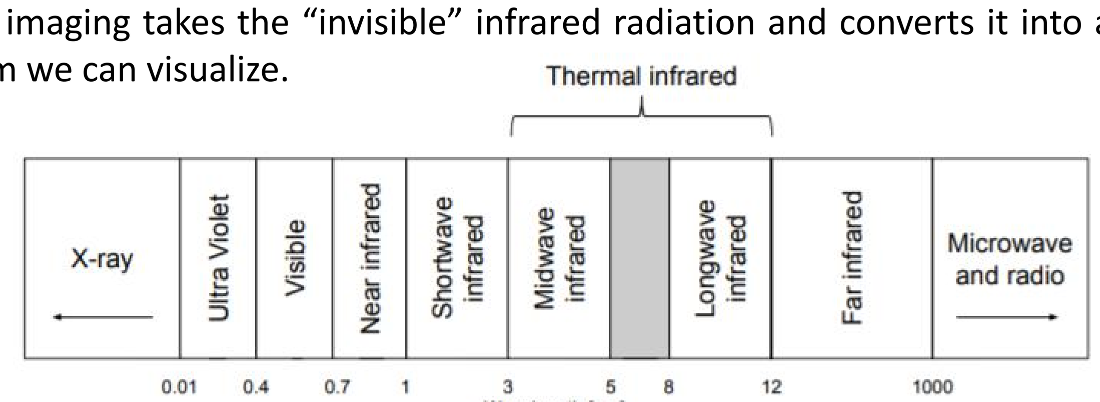
Avoidable recent accidents:

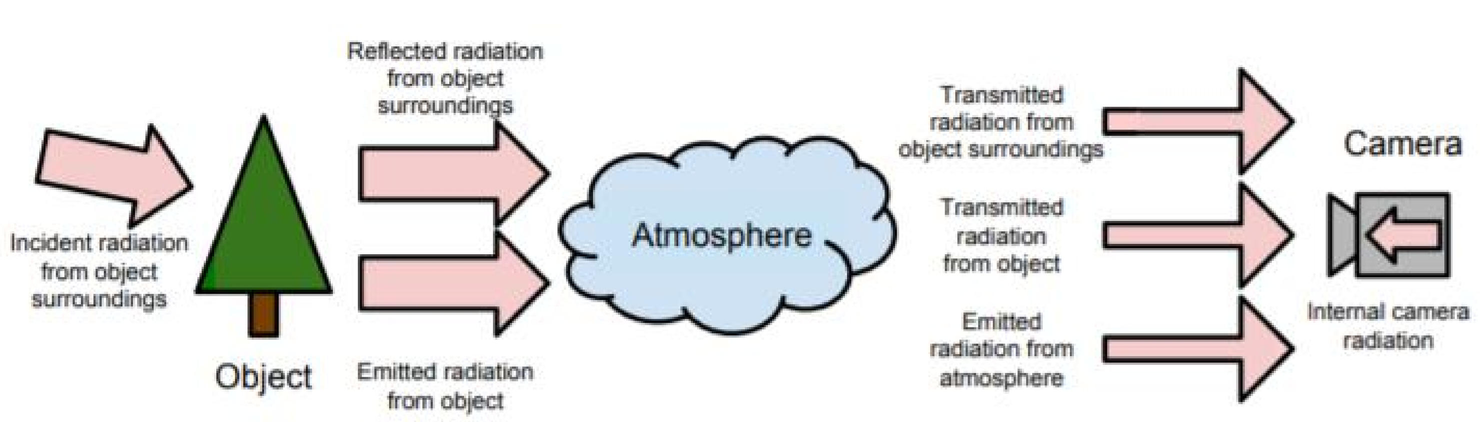
- Jan 22 & Mar 23, 2018: Tesla vehicle (CCD camera, radar, and ultrasonic sensors) on auto-pilot strikes a non-moving object on the road (firetruck and concrete lane divider)
- Mar 18, 2018: First recorded **pedestrian** death by an Uber self-driving Volkswagen (camera, radar, and LIDAR systems)
  - Death caused by limited visibility and the radar and LIDAR systems not detecting the crossing pedestrian



WHAT IS INFRARED (IR) IMAGING?

- One of the seven types of electromagnetic radiation.
- All bodies will emit infrared light. The intensity of this light is dependent on their temperature.
- Infrared imaging takes the "invisible" infrared radiation and converts it into a visible spectrum we can visualize.





LEVERAGING IR FOR DETECTION

Advantages

- Warm bodied objects exhibit high contrast in cold environments, making them easily identifiable
- No dependence on visible light with better performance during nighttime applications
- Offers more detail on small, warm objects than LIDAR and radar
- No blooming effects from lights in the camera's FOV
- Minimal shadow effects

Disadvantages

- Expensive (low economies of scale)
- Low levels of image detail
- Low image information content when no warm bodies are present in an image
- Image appearance (and therefore algorithm performance) is dependent on the weather conditions
- Atmosphere absorbs IR meaning measured temperature readings may not be accurate

DESIGN CONSTRAINTS AND CAMERA CAPABILITIES

Detection and tracking algorithm will receive raw information from a **FLIR A65** thermal imaging camera.

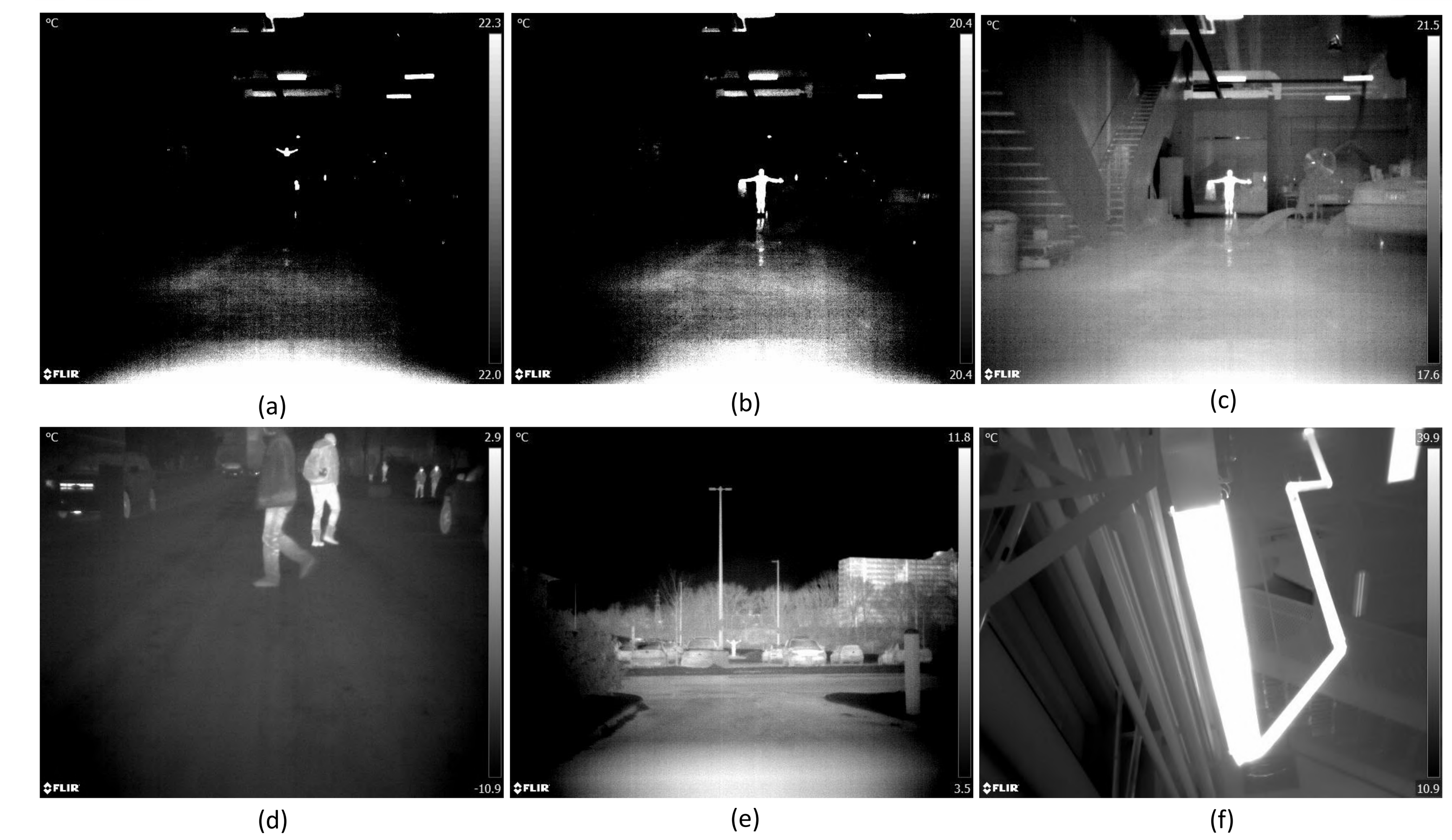
Reaction time: Must be able to detect and respond to a visual stimulus faster than a human driver. The average human reaction time is approximately 0.25s. Aiming to achieve 0.1s reaction. Camera has a frame rate of 30 Hz.

Detection Range: 60m minimum range for detecting a pedestrian. Vehicle speed assumed to be 100 km/h with a braking distance of ~55m. Camera is capable of detecting a person from 4.5-150m

Field of View (FOV): As living things, especially wildlife, will usually appear from the driver's peripherals, a wider FOV is desired. FLIR A65 offers a FOV of 45° x 37°, which offers full single lane detection at 3.6m.

Resolution: Higher resolution costs more but allows for a wider FOV or larger detection range. Camera has a resolution of 640x512 pixels.

SAMPLE IMAGES



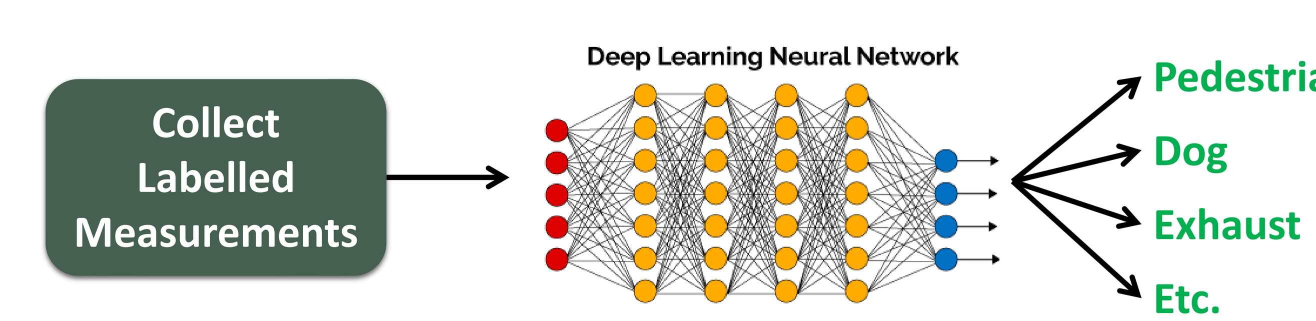
(a) Two partially occluded people at 42m; (b) A person at 20m; (c) Same image as B but different temperature scale; (d) Pedestrians crossing the street; (e) Person at 64m; (f) Indoor heating element

HOW TO DETECT AND CLASSIFY

Detection: Filter the raw image using image hotspots and intensity with strategies including optical flow to create a binary image for object classification.

Classification: Coarse level classification based on shapes and sizes of living surroundings using support vector machines (SVM). Fine grain classification using convolution neural networks (CNN) complemented by an expandable library.

Basic Research: Supervised training strategies using smooth variable structure filter (SVSF) complemented by unsupervised adaptation of the library using ALOPEX.



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