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A UAV-Based Methodological Approach for In-Situ Method Calculation of Thermal Transmittance (U-value) in Historic Building Envelopes using Quantitative Infrared Thermography (QIRT)

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A **UAV-based** methodological approach for in-situ method calculation of **thermal transmittance (U-value)** in historic building envelopes using **quantitative infrared thermography (QIRT)**

Agenda

- **Introduction**
- **Aims**
- **U-value Calculation**
- **Workflow of UAV-QIRT**
- **Conclusions and Next Steps**

40%

Energy Consumption

75%

Energy Inefficient

35%

Over 50 Years Old

A Crucial Parameter

Thermal Transmittance (U-value; W/m^2K) represents the heat transfer per unit area through a building envelope due to a temperature difference between indoor and outdoor air.

U-value Assessment

- Designed U-value
- U-value by Heat Flux Meter sensors (HFM)
- U-value by Quantitative Infrared Thermography (QIRT)

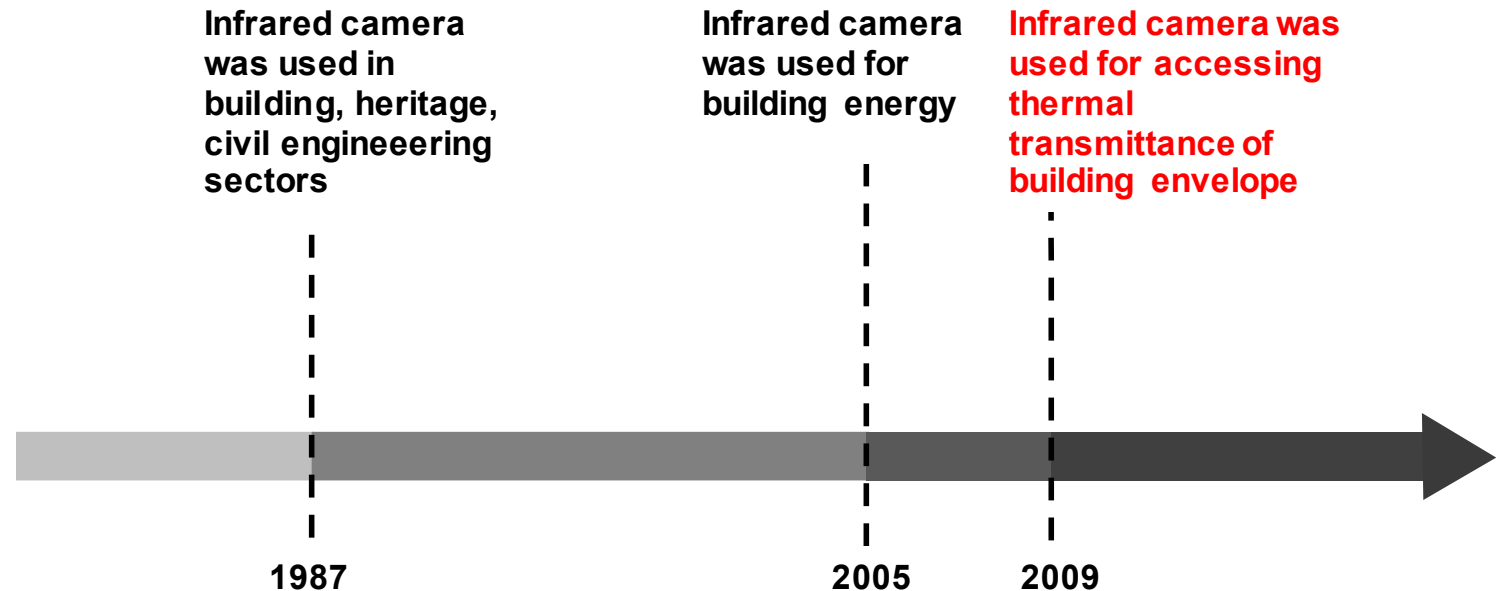


Thermogram by FLIR T1020 Thermal Camera. FLIR

Quantitative Infrared Thermography (IRT)

Infrared thermography (IRT) is primarily used for qualitative analysis to visually assess building defects like structural issues, insulation, and air leaks.

Quantitative infrared thermography (QIRT) is rapid, efficient and non-invasive as a promising alternative to HFM method.



A Brief history of infrared thermography

UAV-QIRT

Unmanned Aerial Vehicles (UAVs) equipped with infrared cameras offer the potential for historic building inspection.

- ✓ Accessing Hard-to-Reach Areas
- ✓ Broad and Detailed Thermal Views
- ✓ Non-Invasive



DJI Matrice 350 RTK with Zenmuse H20T Sensors. DJI

U-value Calculation by QIRT

It is calculated by dividing the heat flux, q , by the temperature difference between the indoor (T_{in}) and outdoor (T_{out}) environments.

$$U\text{-value} = \frac{q}{T_{in} - T_{out}}$$

For outdoor in-situ measurements, the data from the UAV-QIRT are used to calculate the U-value according to the equations:

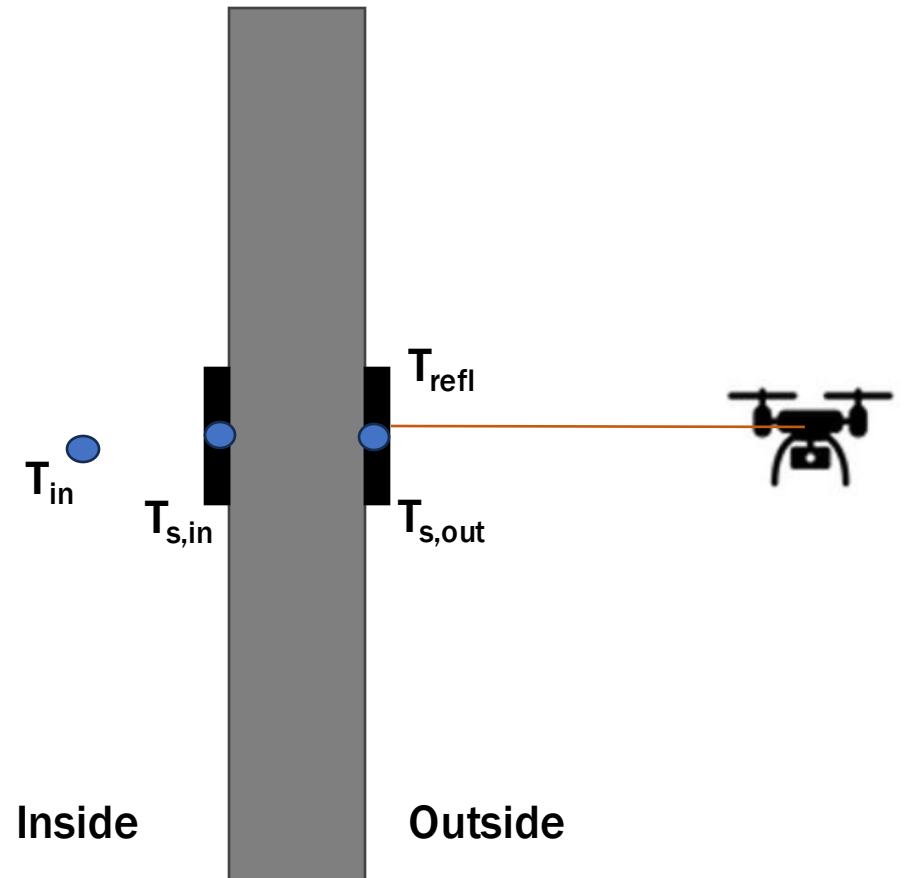
$$U = \frac{\varepsilon_v \sigma (T_s^4 - T_{out}^4) + 3.8054 \nu (T_s - T_{out})}{(T_{in} - T_{out})} \left[\frac{W}{m^2 \cdot K} \right]$$

$$U = \frac{\varepsilon \sigma (T_{refl} - T_{s,in}) + h_c (T_{in} - T_{s,in})}{T_{s,in} - T_{s,out}}$$

U-value Calculation by QIRT

$$U = \frac{\overset{\text{Radiative Energy}}{\varepsilon\sigma(T_{refl} - T_{s,in})} + \overset{\text{Convection Input}}{h_c(T_{in} - T_{s,in})}}{T_{s,in} - T_{s,out}}$$

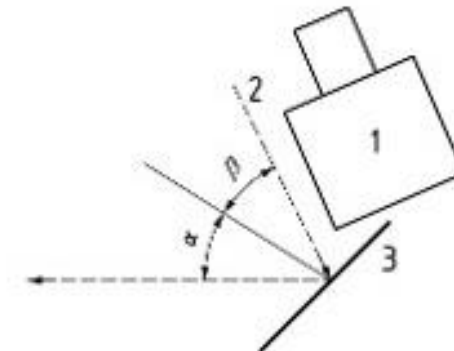
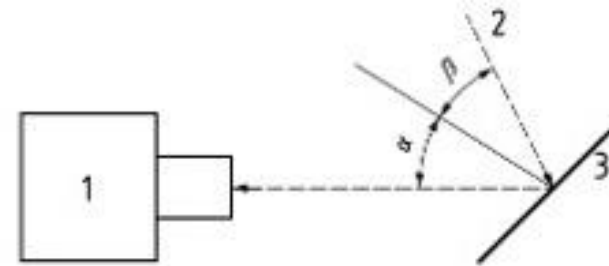
ε is the wall emissivity, σ is the Stefan-Boltzmann constant ($5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$), and h_c is the convection coefficient set at $8.7 \text{ W/(m}^2\text{K)}$.



UAV-QIRT Workflow

The proposed acquisition process is based on the [BS EN ISO 6781-1:2023](#) standard.

1. Environmental conditions.
2. Instruments selection and preparation.
3. Capture thermograms and calculate the reflected apparent temperature (T_r)

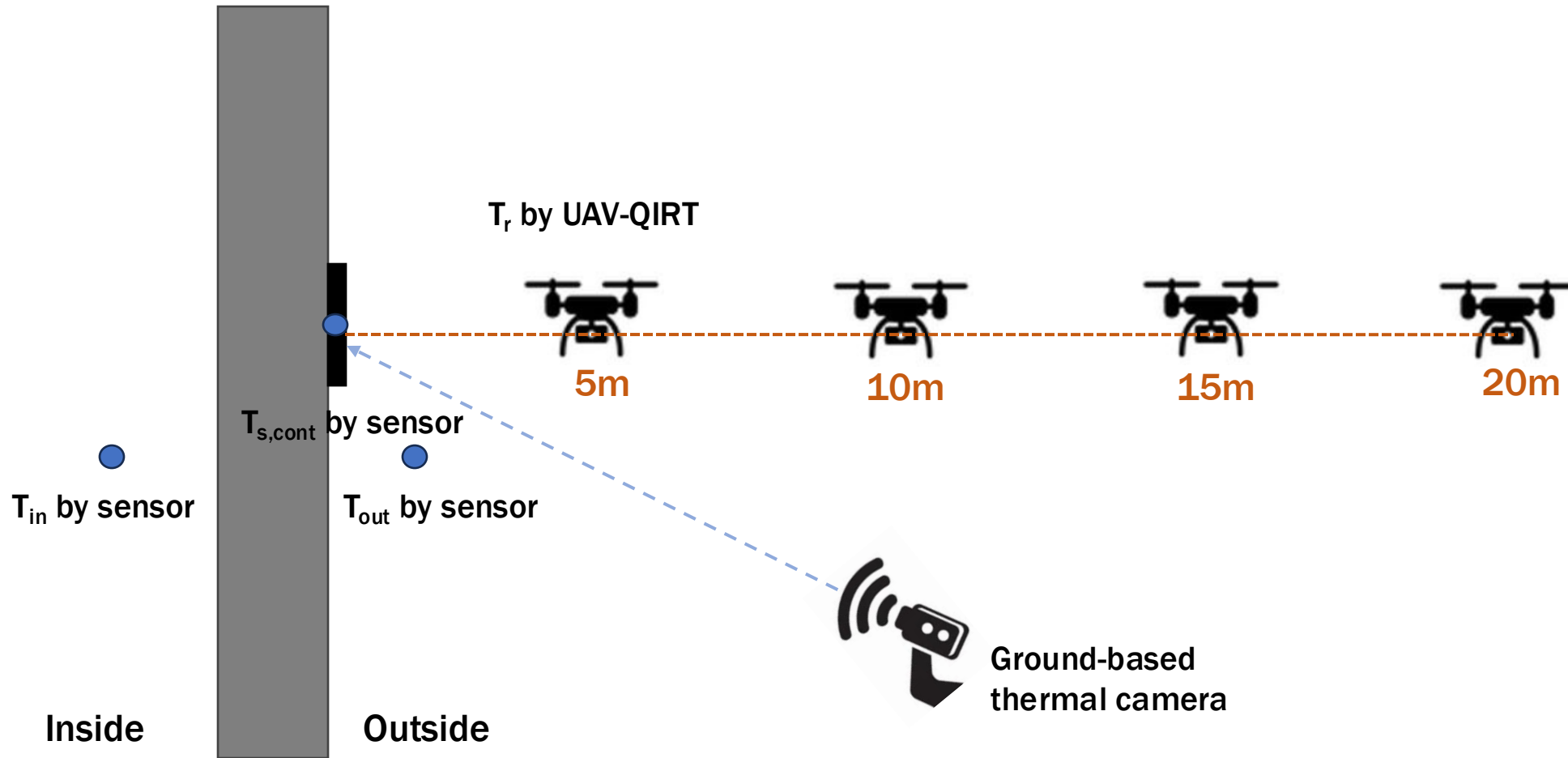


Apparent reflected temperature (T_r) acquisition scheme according to BS EN ISO 6781-1:2023 standard (1 IRT camera, 2 reflected heat source, 3 target, α angle of reflection, β angle of incidence).

Next Steps

Validating the accuracy of the temperature readings captured by the UAV's thermal camera is a priority.

- 1. In-situ measurements will be taken at 5–30 m to assess UAV-induced convection on wall surfaces.**
- 2. UAV thermographic data will be compared with ground-based thermal camera results.**
- 3. The calculated U-values will be compared with those from the HFM method to assess variability in QIRT calculations with UAV involvement.**



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THANK YOU!

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