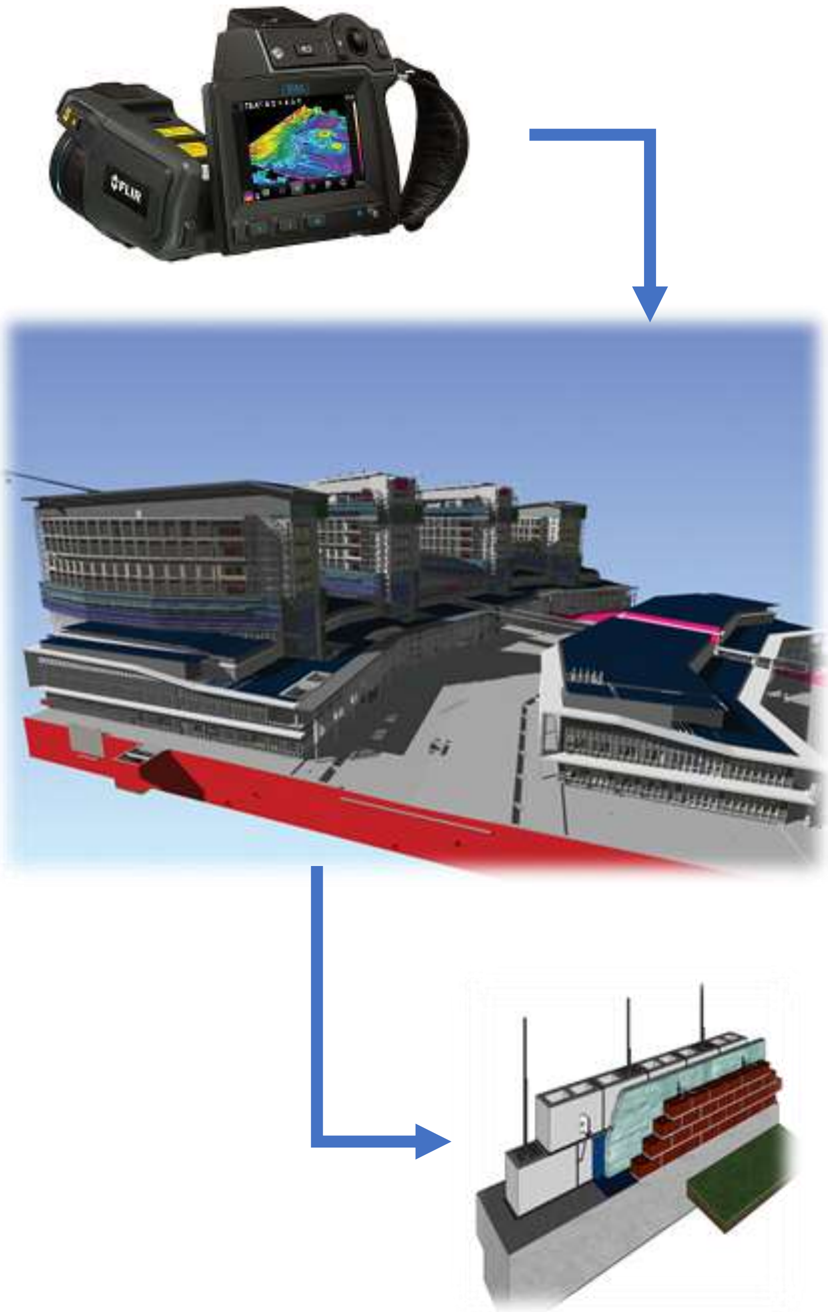


Integration of Textural and Material Information Into Existing BIM Using IR Sensing

A research by:

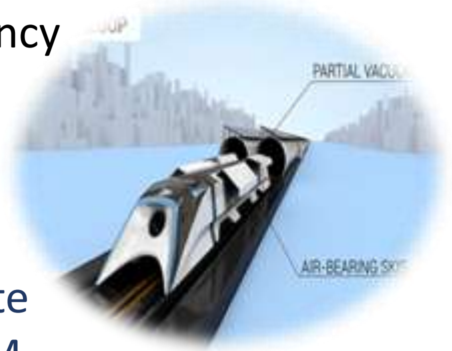
Asem Zabin

Baha Khalil

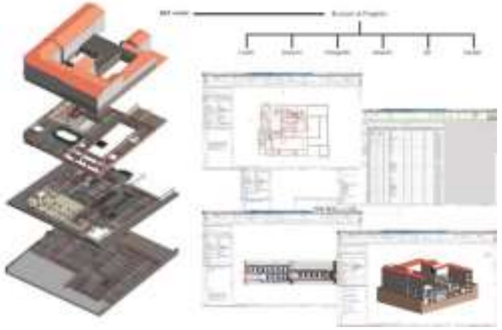
Presenters Background

Asem Zabin

- Senior BIM Engineer at iTech Management Consultancy
- Master of Science in Civil Engineering (MSCE)
- Winner of the **BIM For Innovation** Award for **Hyperloop** Competition



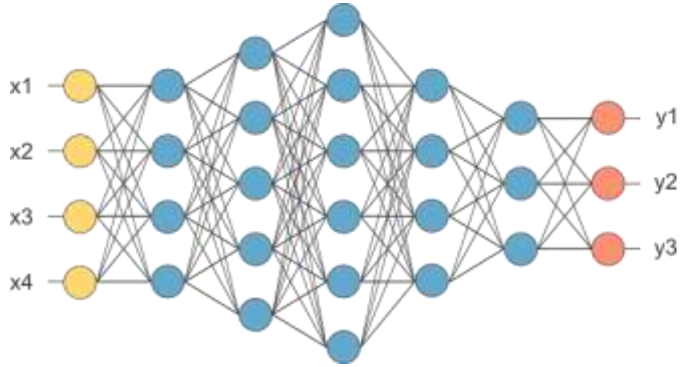
Area of interests: BIM for Infrastructure, Satellite Remote Sensing, As-Built BIM, BIM for FM, Post-construction BIM analysis

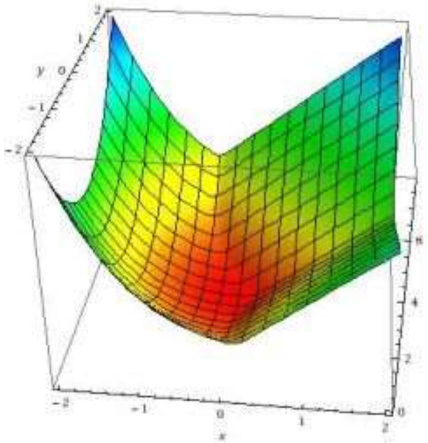


Baha Khalil

- Data Scientist at Unilever
- Master of Science in Mathematics

Area of interests: Convex optimization, Neural networks





Contents

The Problem…

1

Why do we need As-built BIM ?

2

As-built BIM is now done using laser scanners.

- **Limitations**:
  - laser scanners are limited (Only geometry is identified)

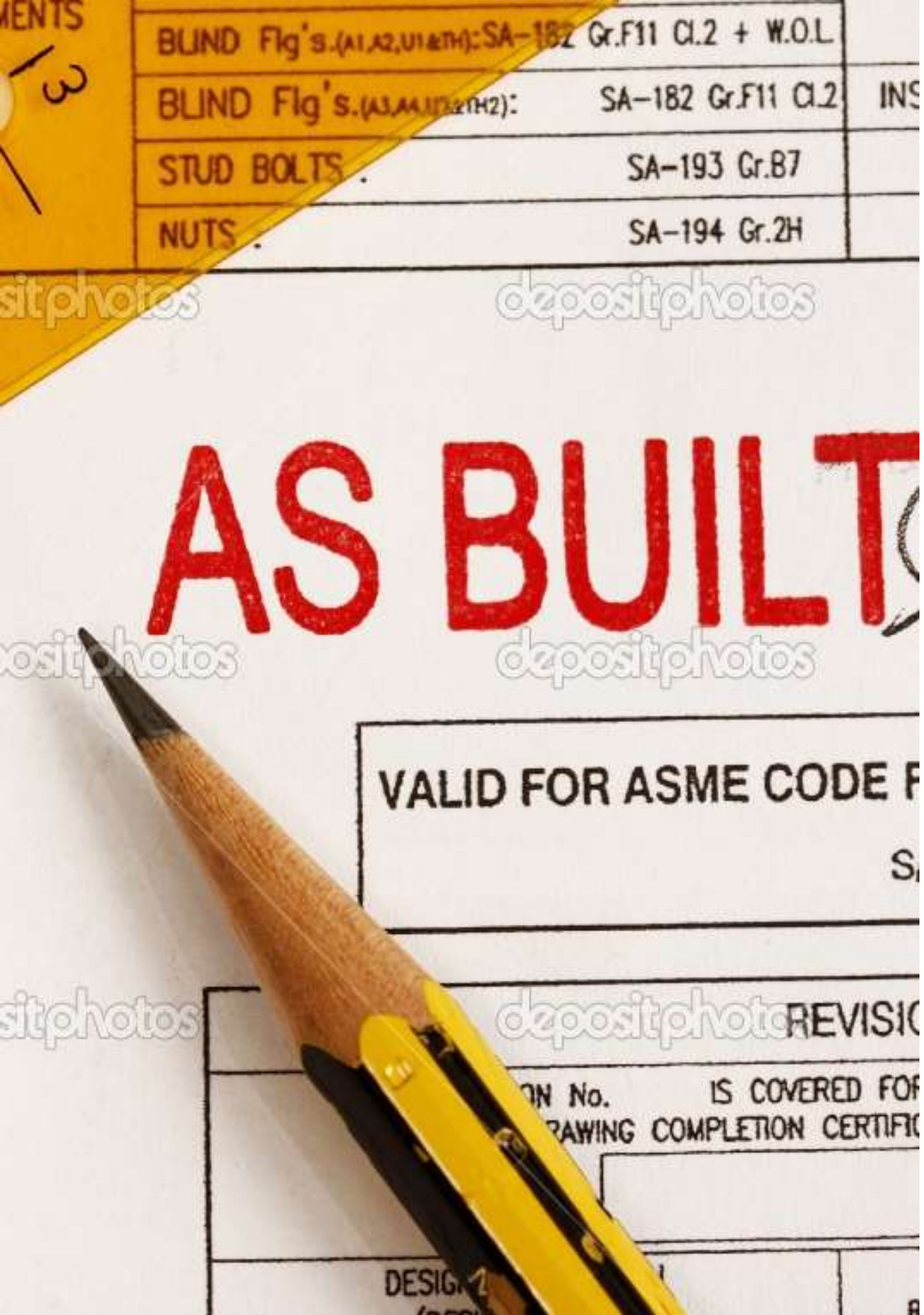
3

Surface Materials?
Texture Homogeneity?

4

Solution

- A Semi-automated method that is able to identify an unknown material and texture and then integrate it with BIM.



Introduction
As-Built

- Definition:
  - Set of drawing and documents submitted by a contractor upon completion of a project or a particular job.
  - Reflect all changes made in the specifications and working drawings during the construction process.
  - Show the exact dimensions, geometry, and location of all elements of the work completed under the contract.
  - Also known as "record drawings" or "as is".

- Applications

Problem Statement

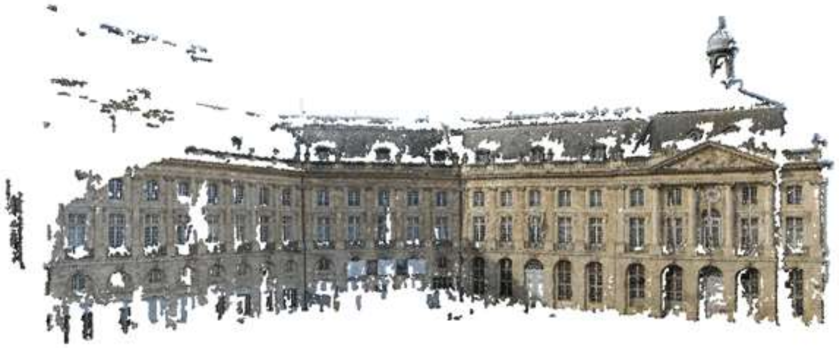
As-Built Drawings

- Rolls of drawings from the architect and engineers
- Folders of equipment information for each type of equipment
- 2D CAD Files

As-built 3D BIM?

Current Data Acquisition Methods

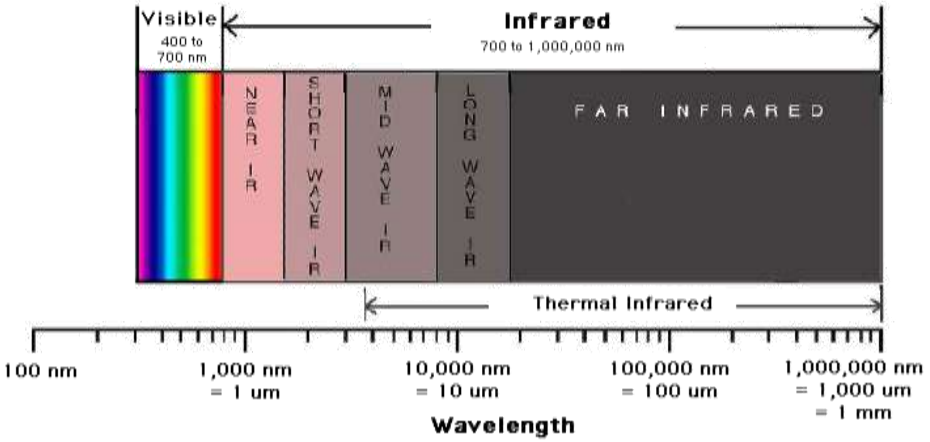
- Use of Barcodes in Construction to extract location information of objects
- Radio Frequency Identification (RFID) tags
- Laser Scanners or Light Detection And Ranging (LiDAR)
- Photogrammetry



Remote Sensing, Infrared (IR)

- Remote Sensing is the science and art of capturing information about objects, areas, or a phenomenon through the analysis of data acquired by device that is not in physical contact with the object, area or the phenomenon.

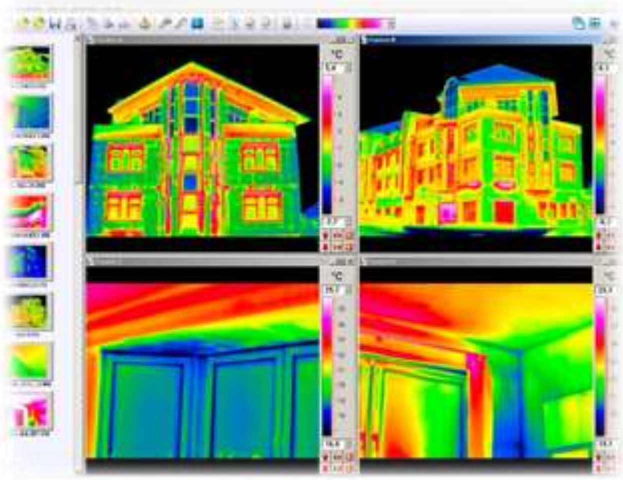
- Infrared (IR) sensing is a form of remote sensing that employs electromagnetic radiations (EMR) between the visible and microwave radiations in the wavelength range from 700 nanometer at the edge of the red to about 1 mm.



Thermal IR Camera

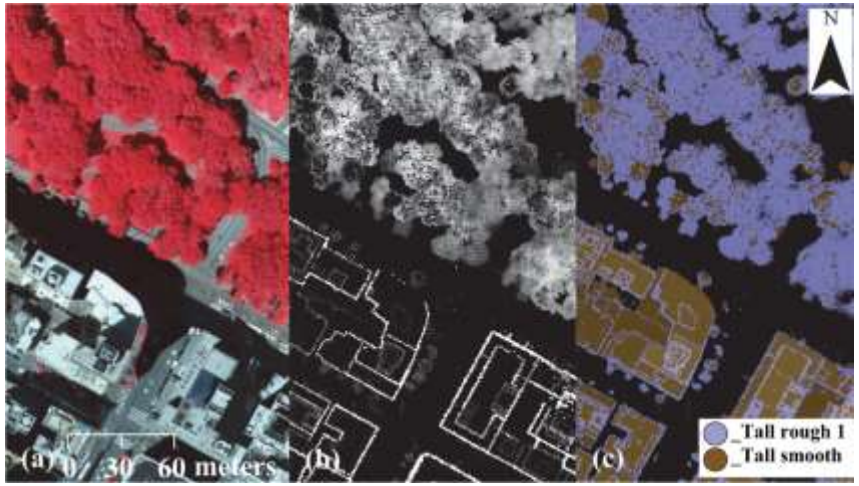
- Advantages in Construction:

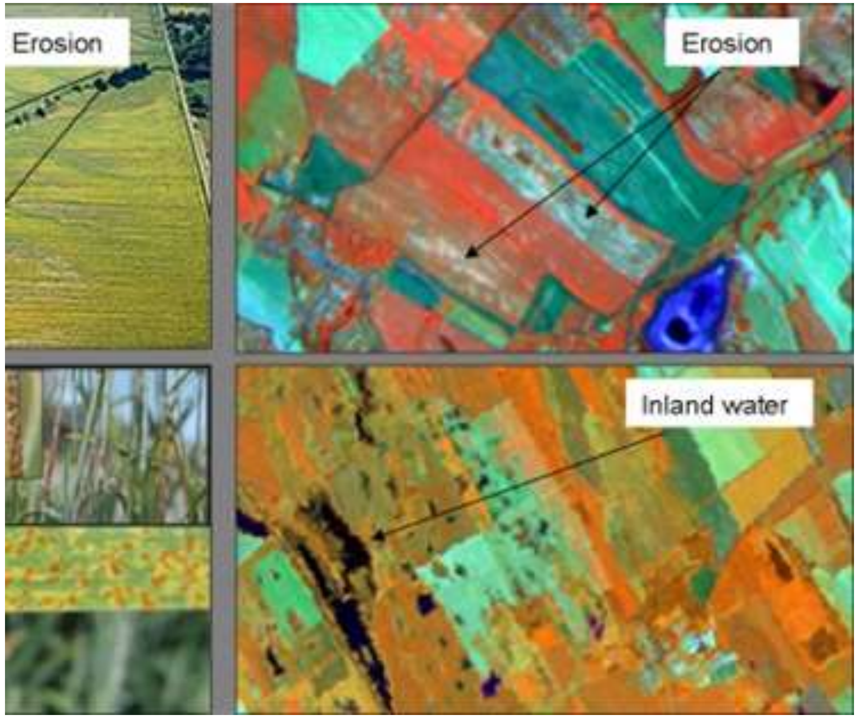
- It’s contactless, therefore nondestructive and reactionless.
- It can be used to measure objects in very hot and difficult-to-access areas.
- It allows for rapid data acquisition.
- It measures the temperature of a solid-state body surface not the surrounding atmosphere.



Texture

- Image texture is the frequency of tonal change of an image
  - Smoothness
  - Coarseness
  - Heterogeneity of classes
    - Contrast
    - Uniformity

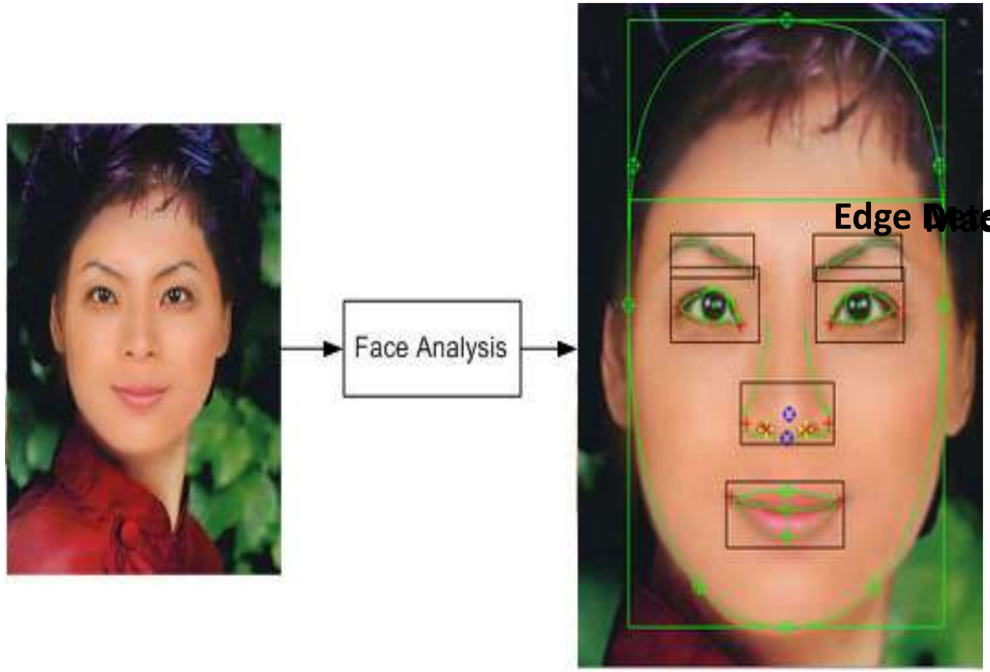




Previous Researches

Texture Extraction

- Over the past decade, multiple striving efforts have been made to make computers acquire, understand, index, and interpret images expressing a wide variety of concepts, with much progress
- The objective is to retrieve texture with high accuracy utilizing the least complicated computational approaches.
- A main form of image processing is image classification, which means segmenting the image into homogeneous zones and labeling the resulted zones with distinct class labels.



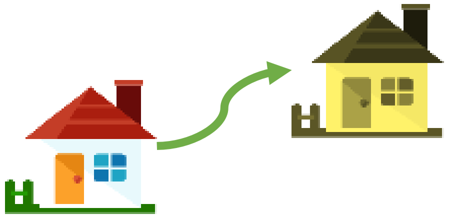
Edge Detection

Machine Learning

Previous Researches

Objectives

- Extract material and textural information of an existing building interior walls using a thermal infrared camera.

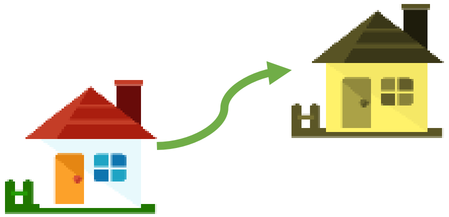


- Develop a framework for representing, organizing, and integrating the acquired material and textural data into the BIM.

- Perform basic analysis on the rich BIM after integrating the new information to explore the advantages and limitations of the study for the industry.

Methodology

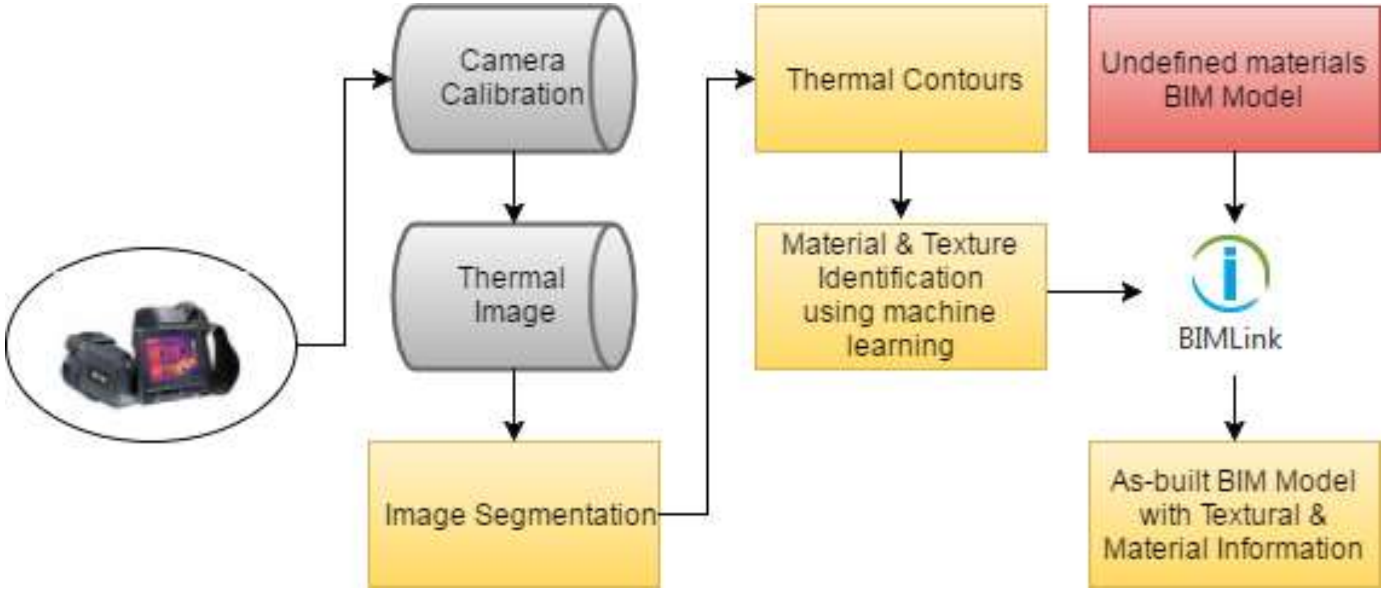
1. Take the picture of the unknown structure



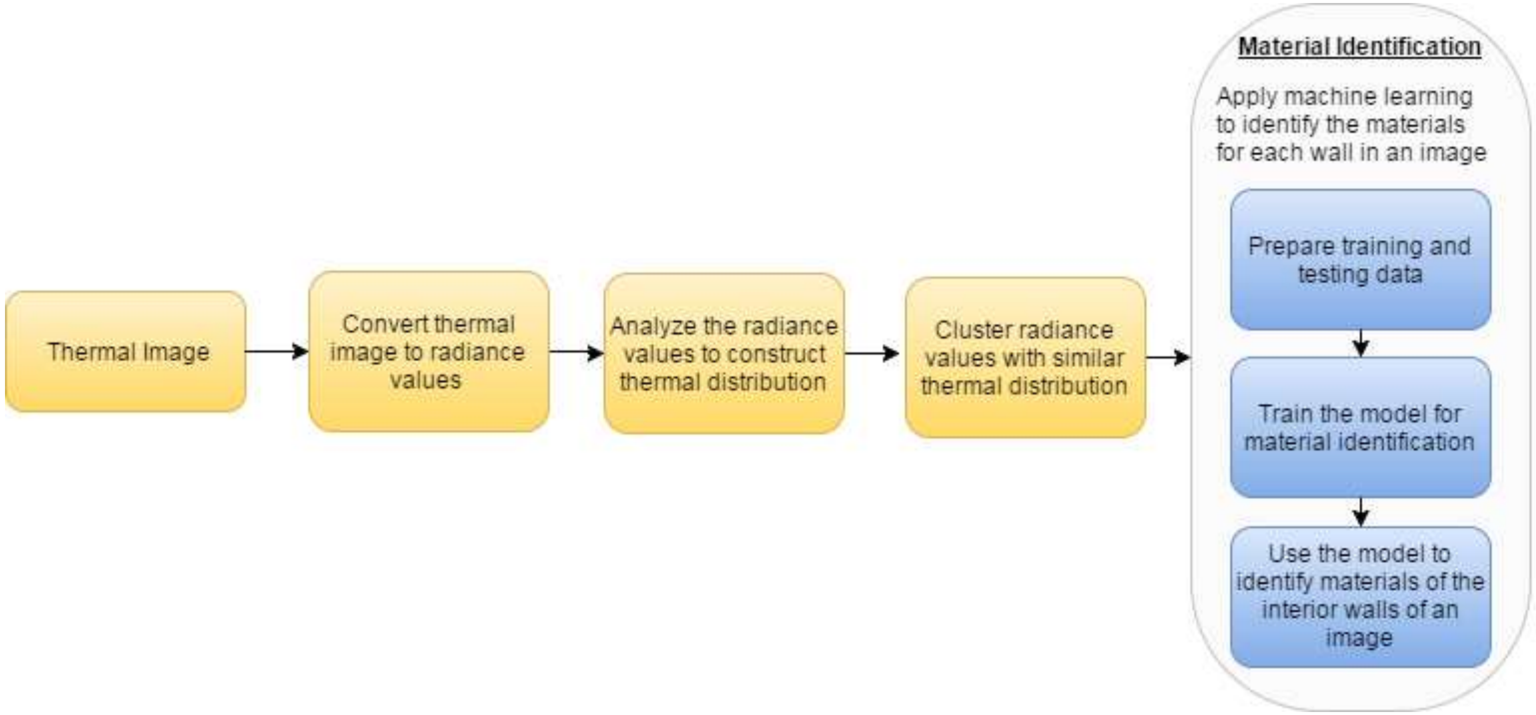
2. Feed the image to the code

3. Algorithm will identify the materials in the provided images

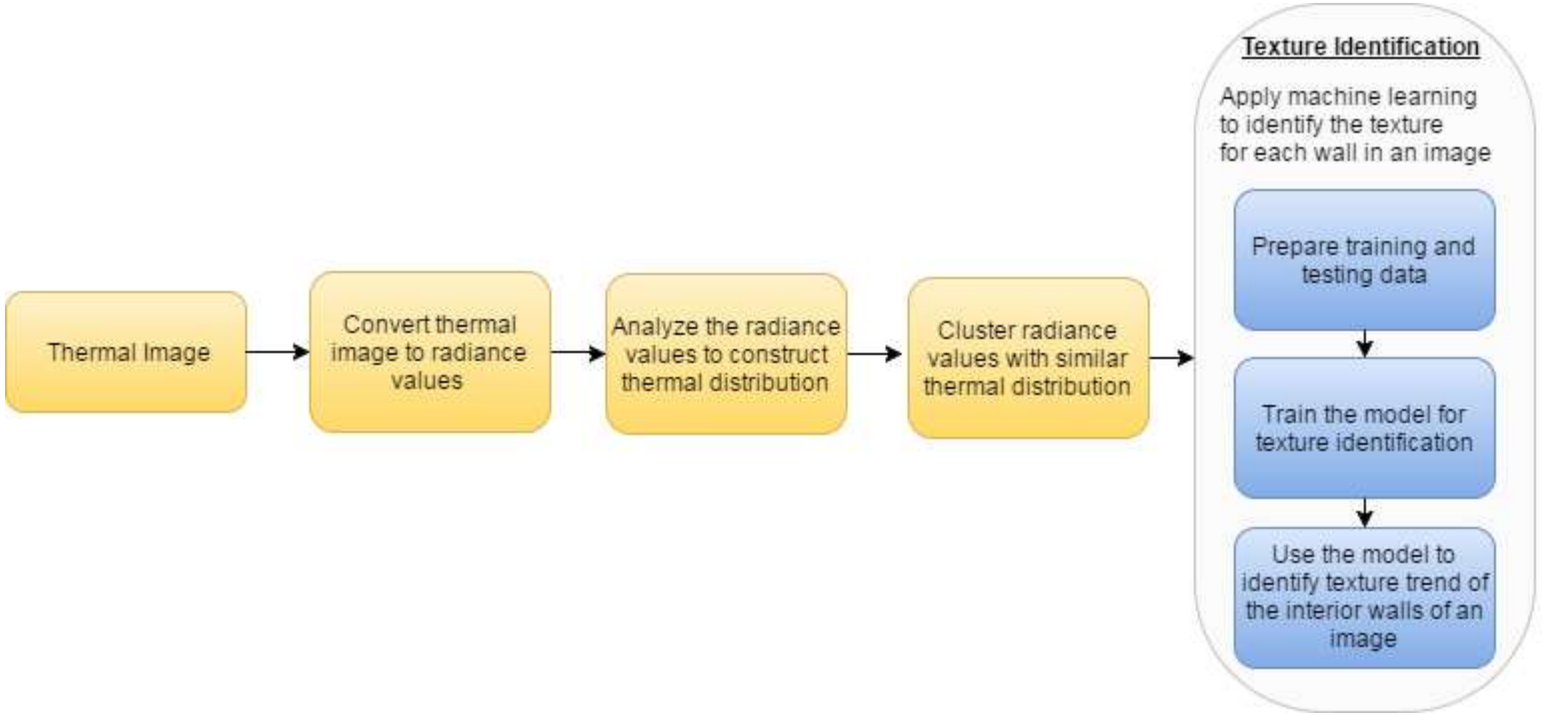
Methodology



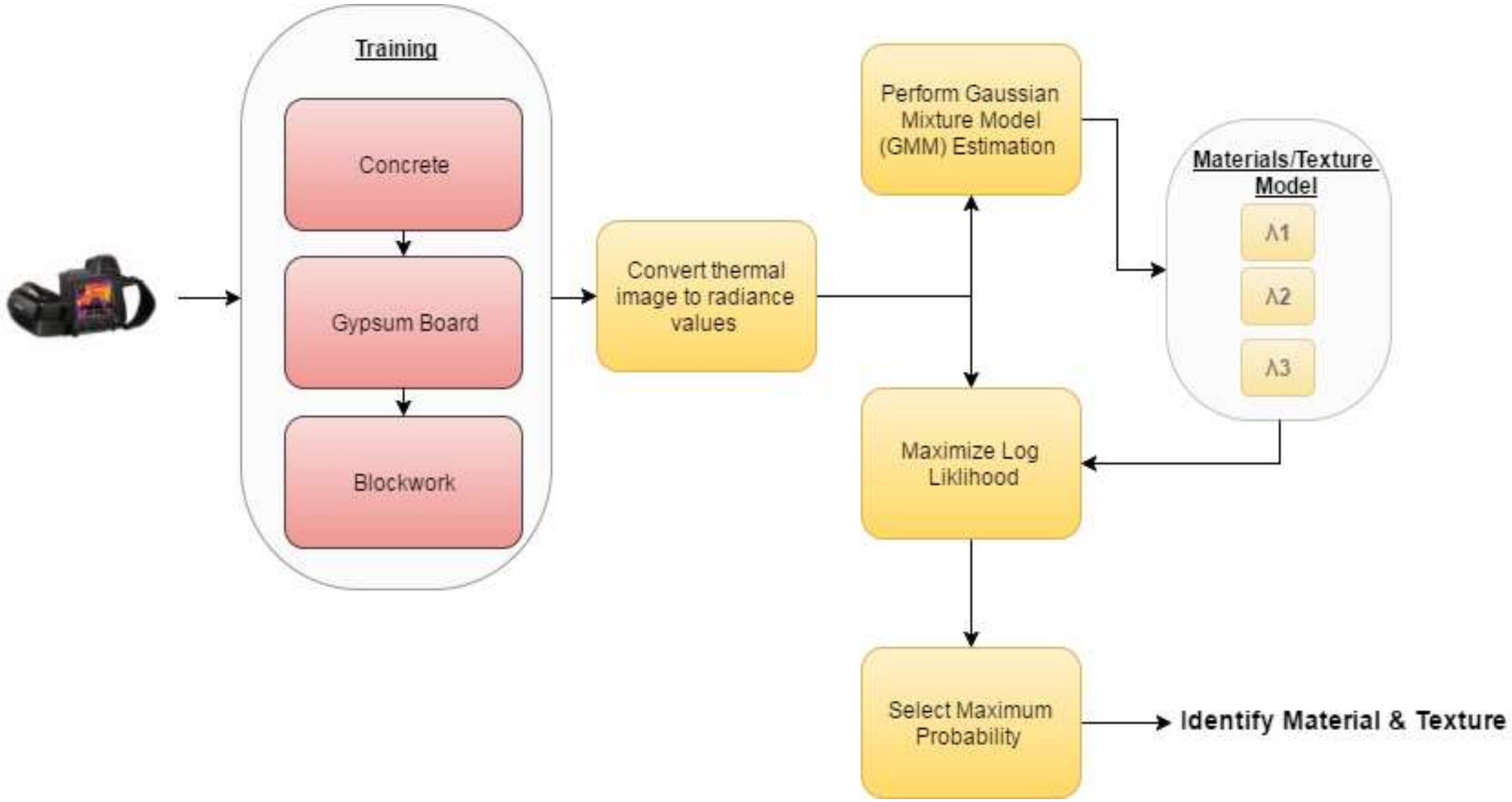
Materials Identification



Texture Identification

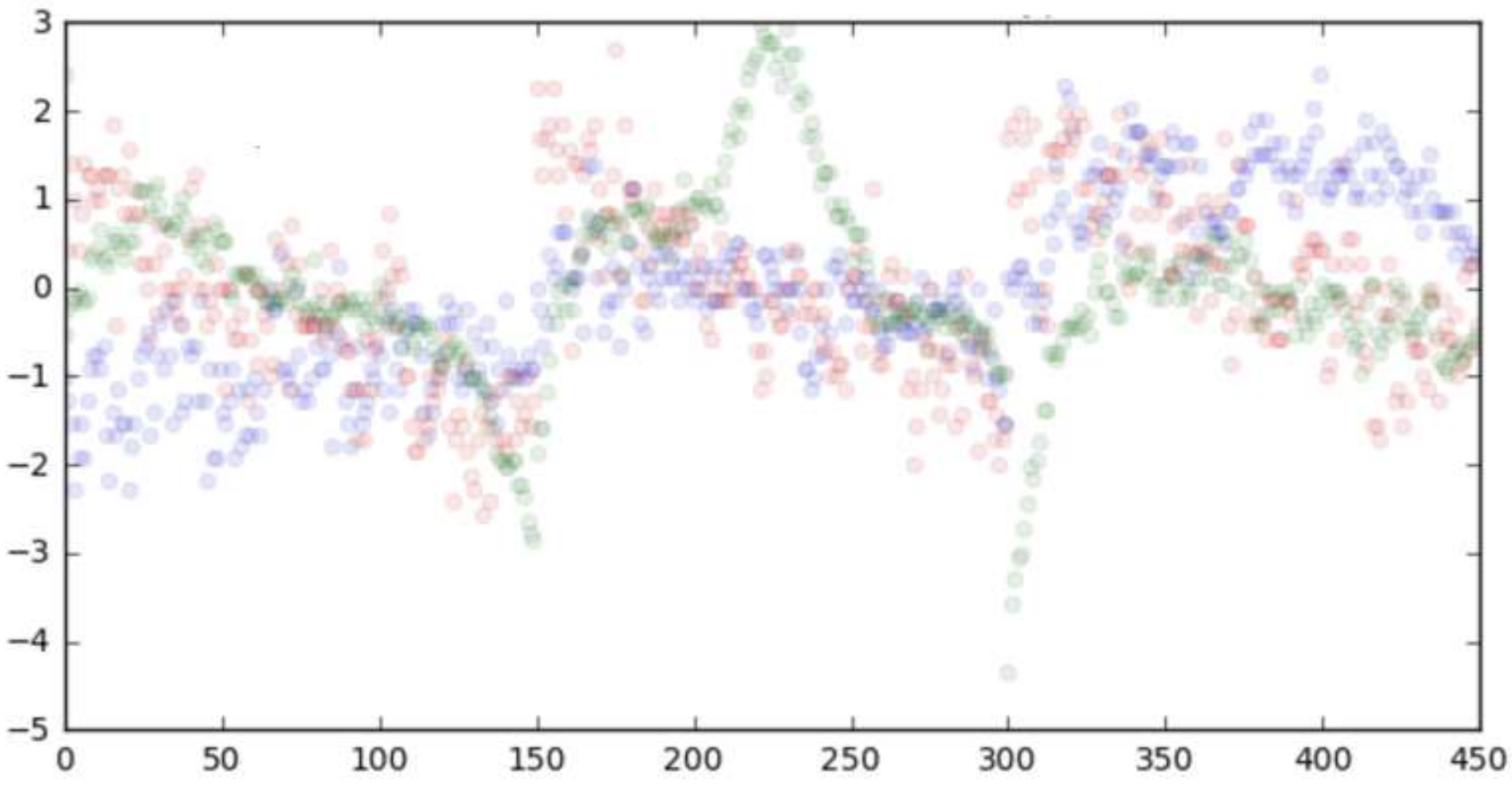


Material and Texture Identification Using Gaussian Mixture Models (GMM)



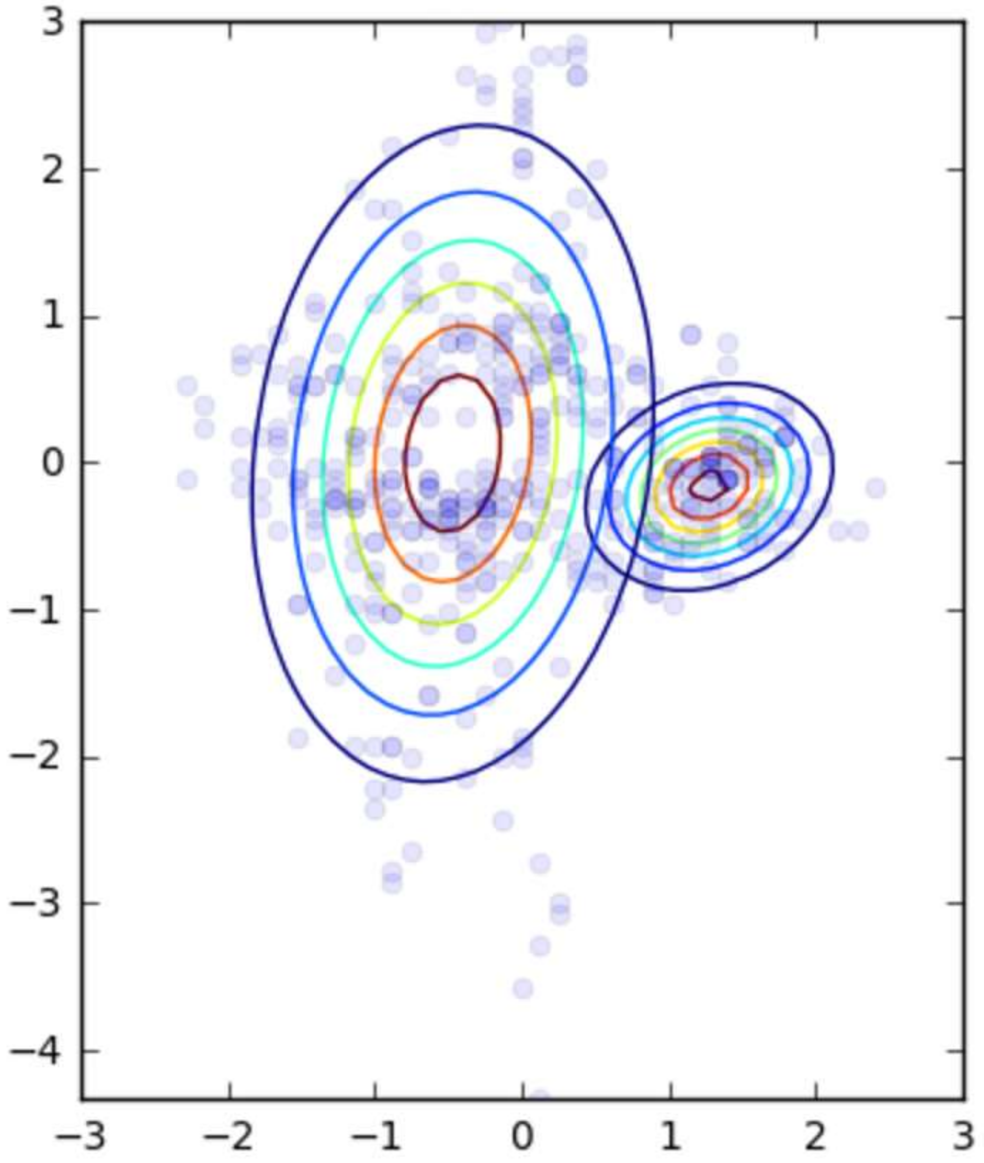
Material and Texture Identification Using Gaussian Mixture Models (GMM)

Normalized Radiance Values of Different Walls Materials



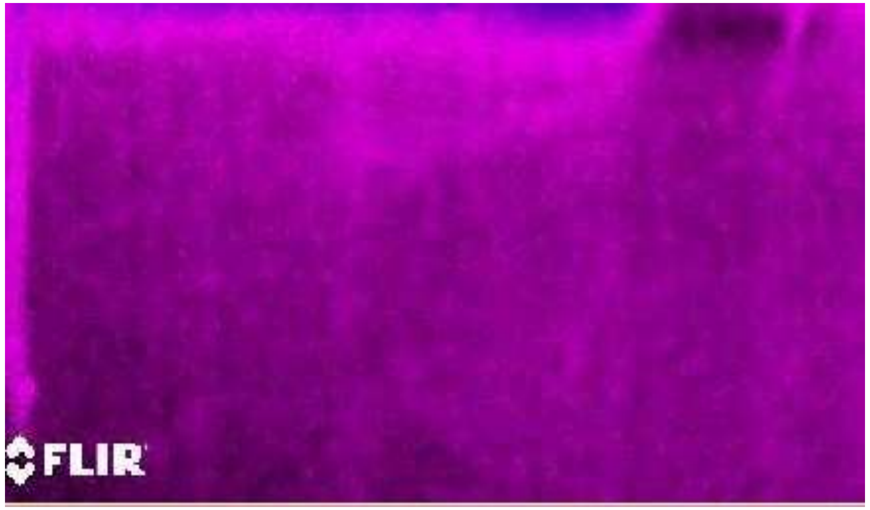
Material and Texture Identification Using Gaussian Mixture Models (GMM)

Gaussian Mixture Models (GMM) for Concrete & Gypsum board

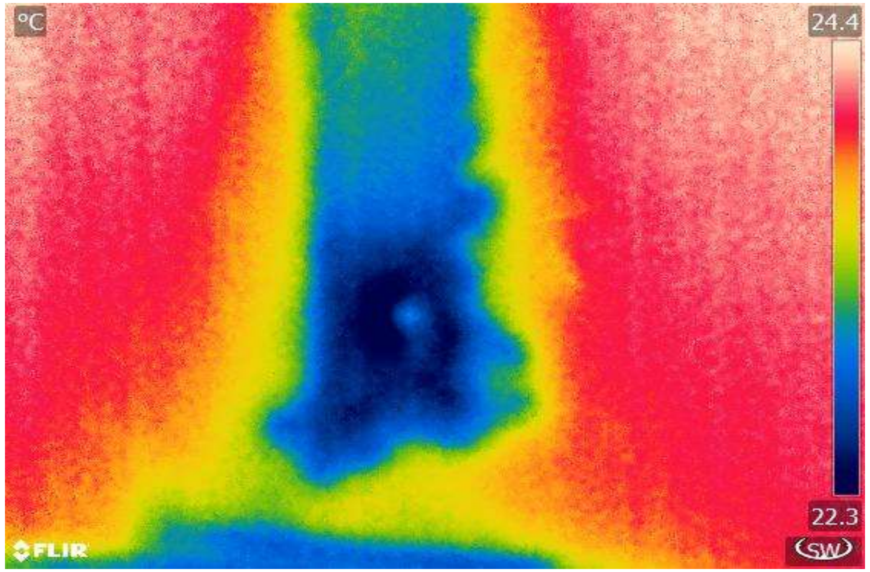


Data Acquisition (Gypsum Board)

Data Acquisition (Concrete)

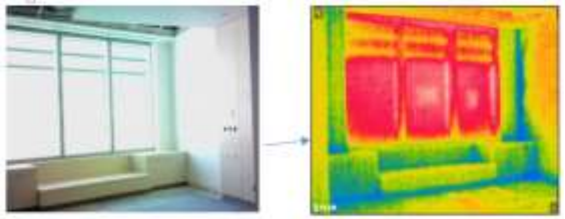


Data Acquisition (Concrete)



Feature Extraction

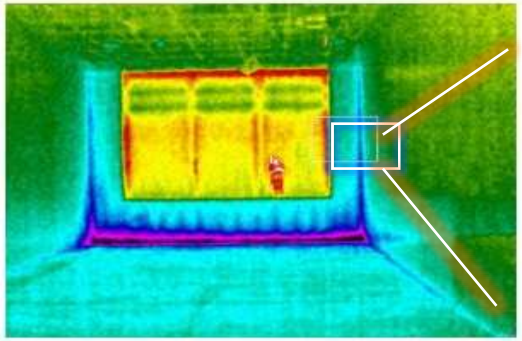
An algorithm which automatically extracts textural information was developed and applied, needed for identification of the walls.



(a) (b)

This texture segmentat
algorithm splits the ima
into different homogen
texture regions

Exploration

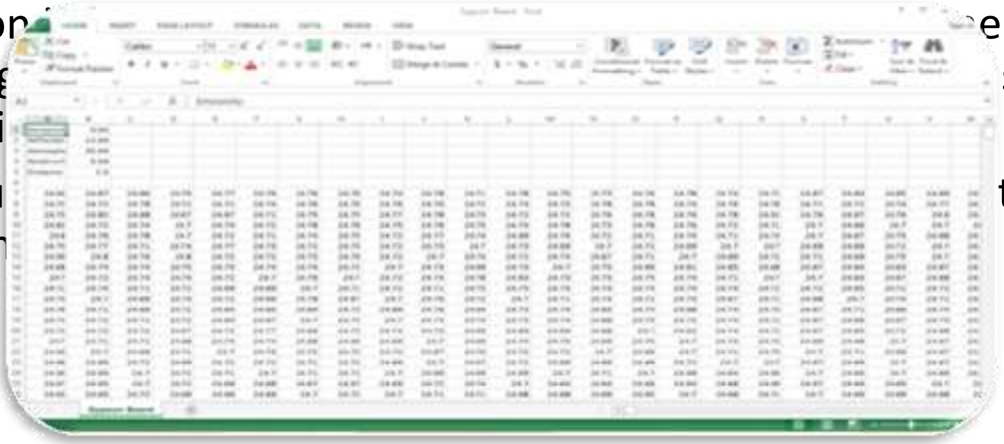


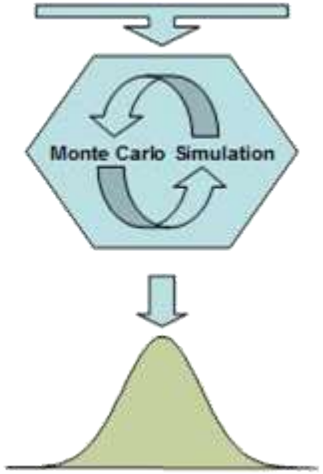
(a)

Materials & Methodology

Data Analysis: Monte Carlo Simulation

- Monte Carlo Simulation ... erates several scenarios and ... ship between the variable i...
- This method is often u... than just a couple uncertain...

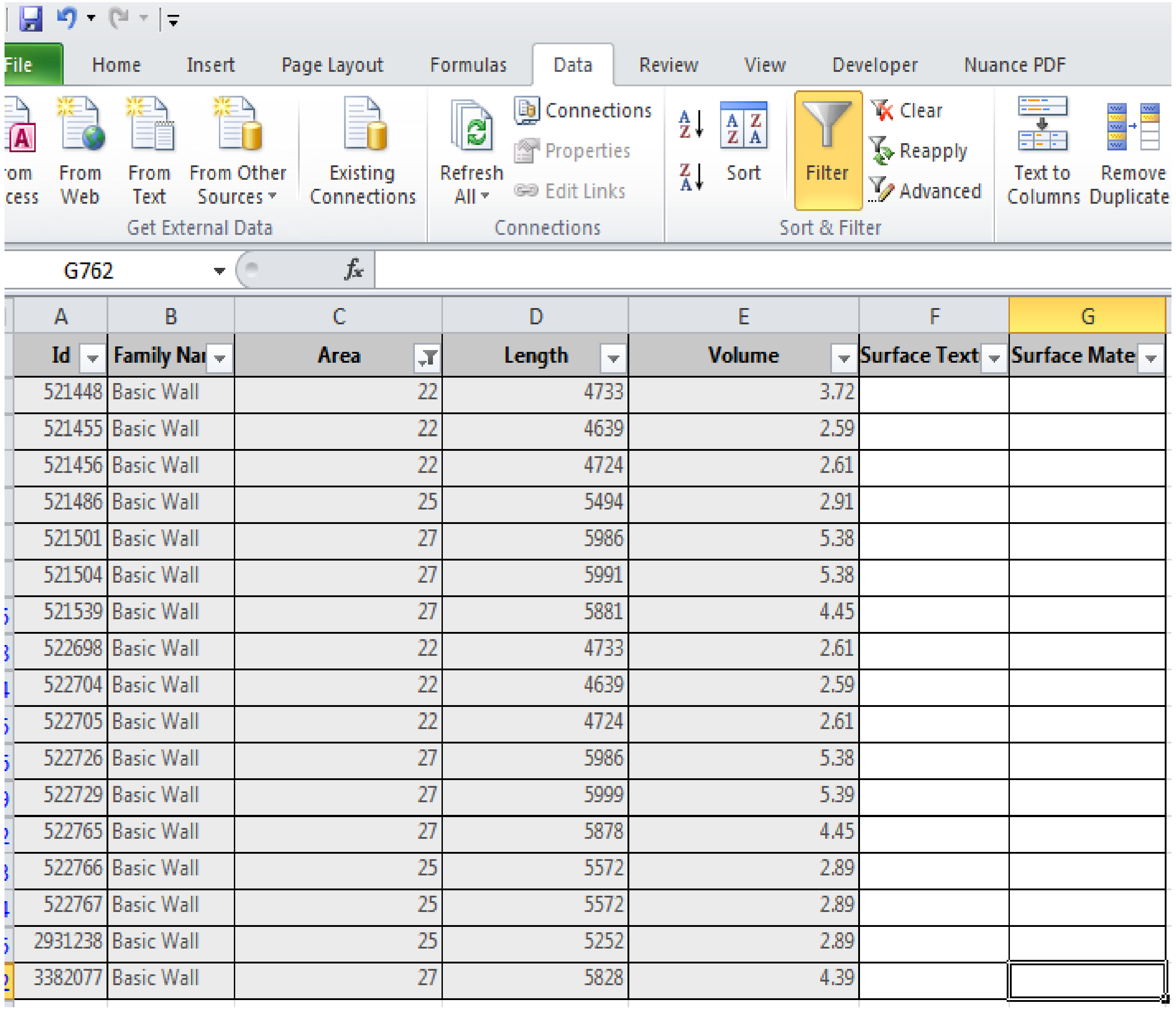




In each scenario, different means and standard deviations were simulated and the relationship between them was noted.

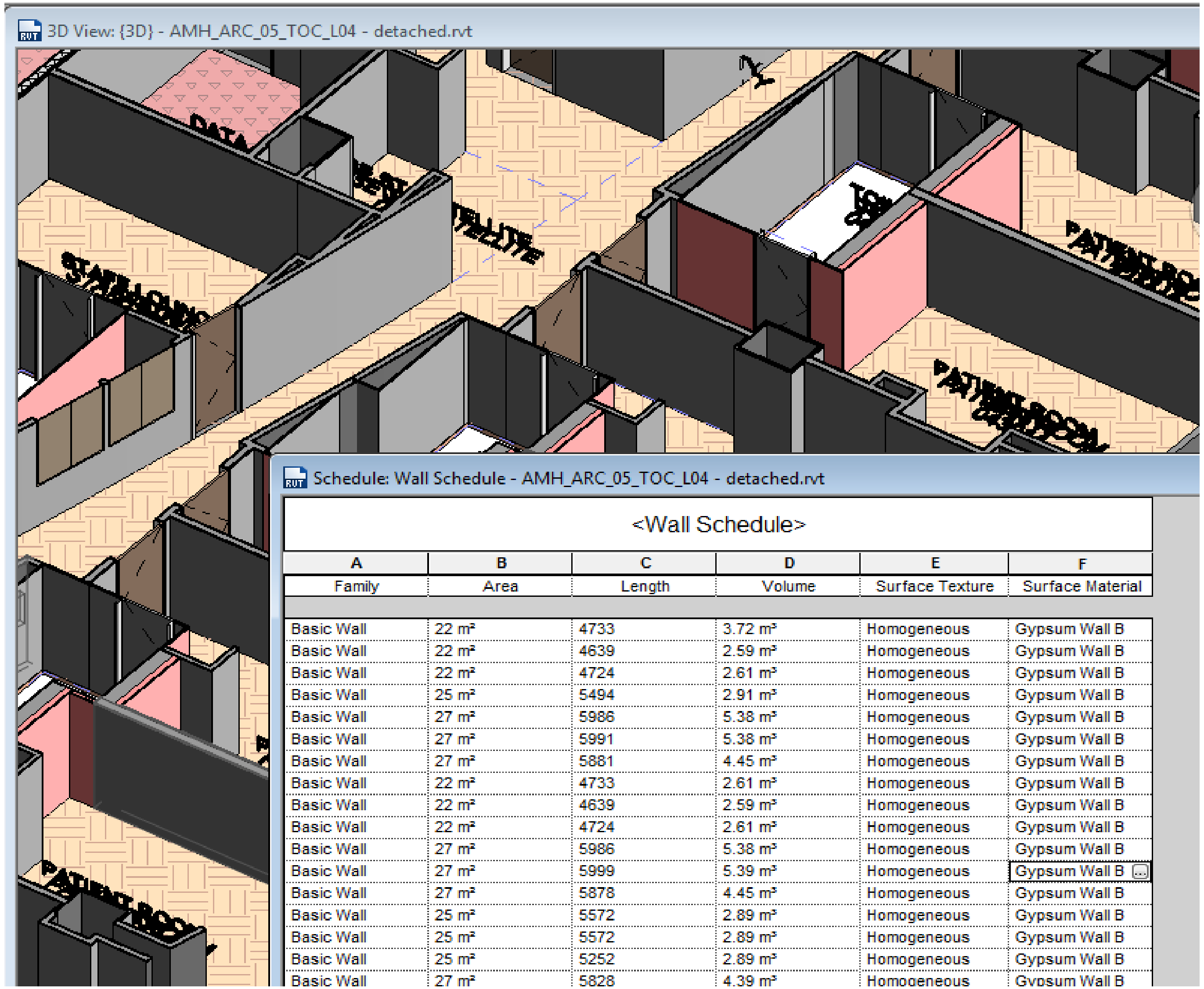
Bell-shape distribution of Radiance values

Results
Data Integration in BIM



Id	Family Nar	Area	Length	Volume	Surface Text	Surface Mate
521448	Basic Wall	22	4733	3.72		
521455	Basic Wall	22	4639	2.59		
521456	Basic Wall	22	4724	2.61		
521486	Basic Wall	25	5494	2.91		
521501	Basic Wall	27	5986	5.38		
521504	Basic Wall	27	5991	5.38		
521539	Basic Wall	27	5881	4.45		
522698	Basic Wall	22	4733	2.61		
522704	Basic Wall	22	4639	2.59		
522705	Basic Wall	22	4724	2.61		
522726	Basic Wall	27	5986	5.38		
522729	Basic Wall	27	5999	5.39		
522765	Basic Wall	27	5878	4.45		
522766	Basic Wall	25	5572	2.89		
522767	Basic Wall	25	5572	2.89		
2931238	Basic Wall	25	5252	2.89		
3382077	Basic Wall	27	5828	4.39		

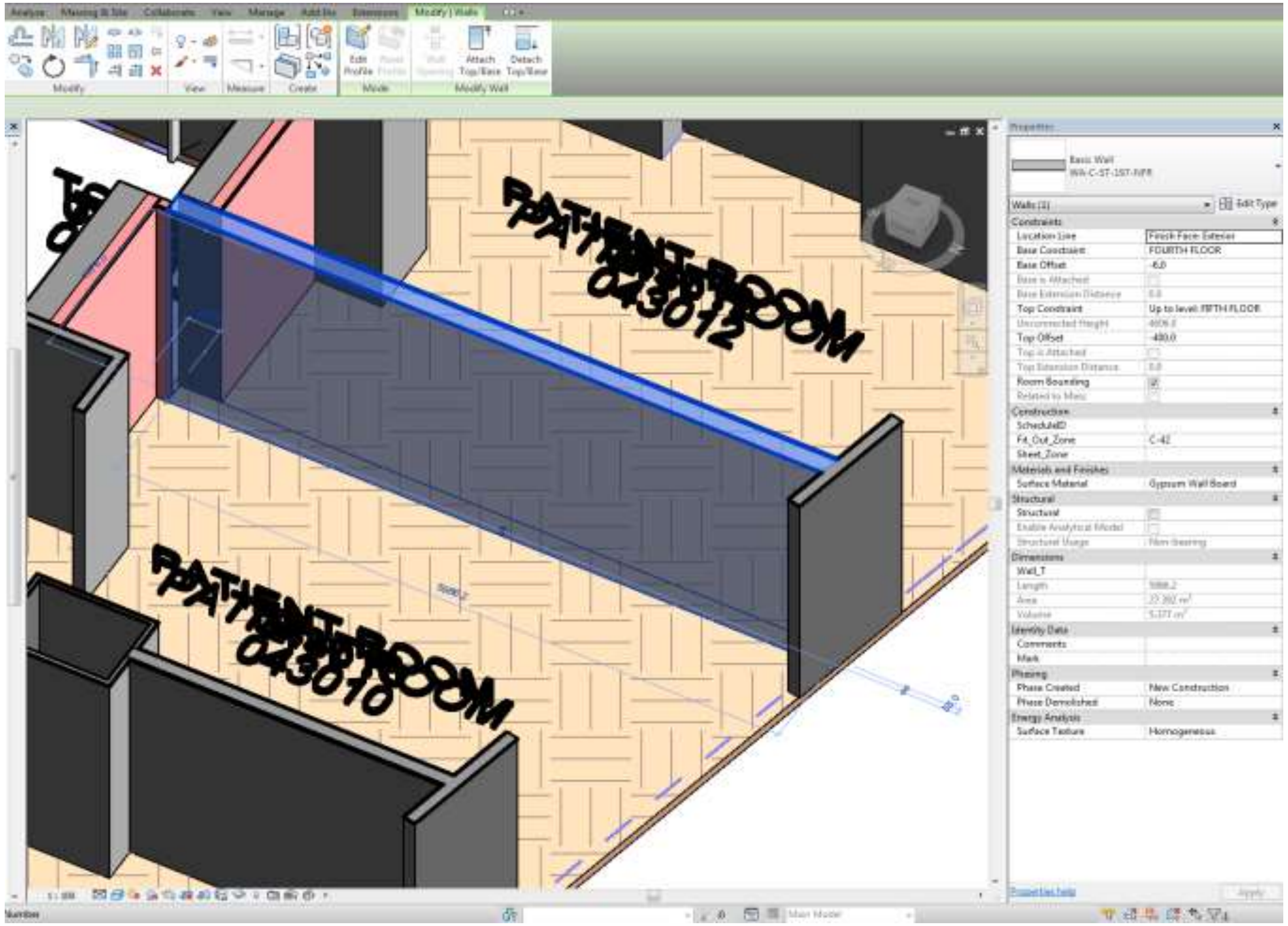
Results
Data Integration in BIM



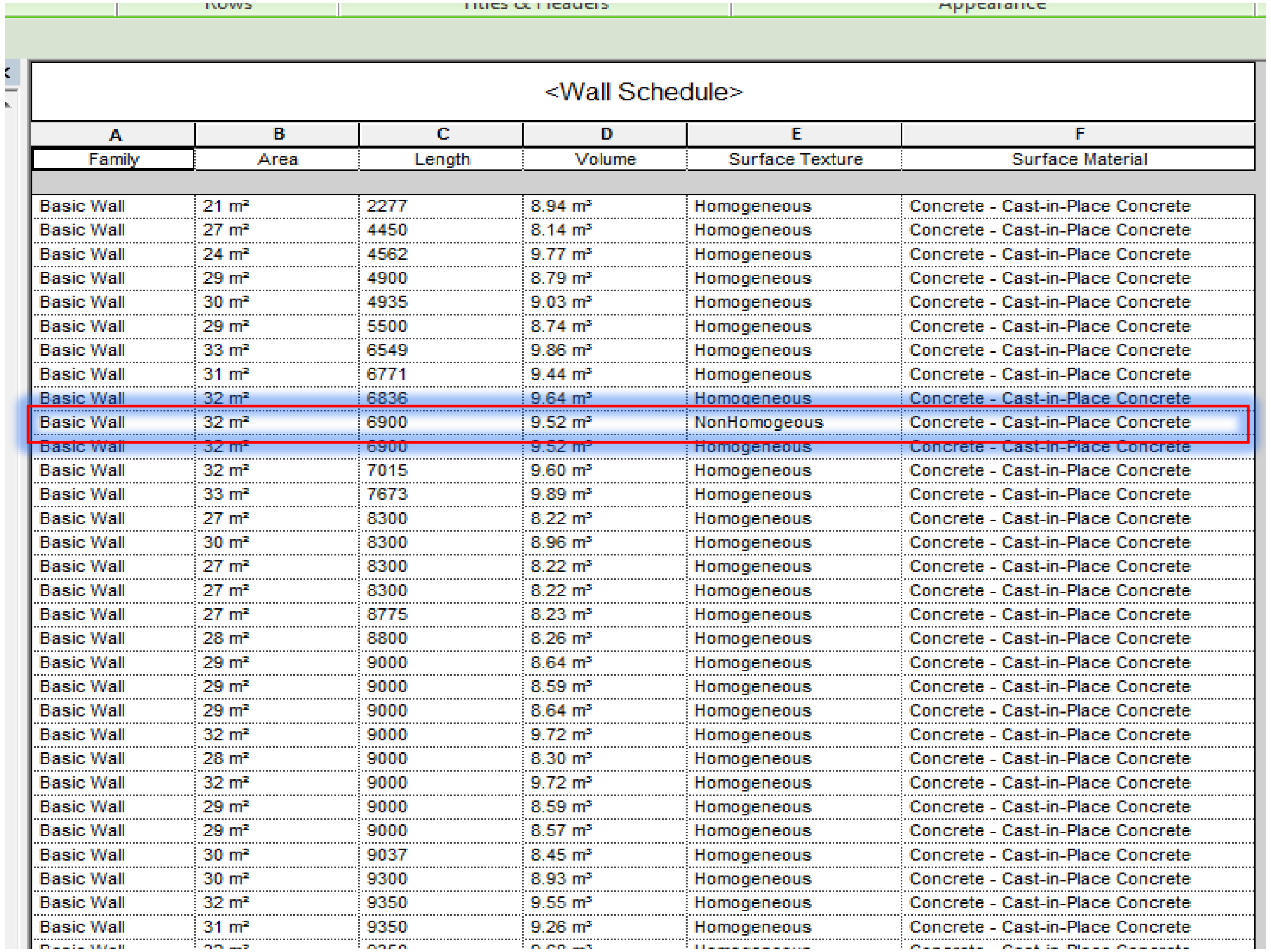
<Wall Schedule>

A	B	C	D	E	F
Family	Area	Length	Volume	Surface Texture	Surface Material
Basic Wall	22 m²	4733	3.72 m³	Homogeneous	Gypsum Wall B
Basic Wall	22 m²	4639	2.59 m³	Homogeneous	Gypsum Wall B
Basic Wall	22 m²	4724	2.61 m³	Homogeneous	Gypsum Wall B
Basic Wall	25 m²	5494	2.91 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5986	5.38 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5991	5.38 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5881	4.45 m³	Homogeneous	Gypsum Wall B
Basic Wall	22 m²	4733	2.61 m³	Homogeneous	Gypsum Wall B
Basic Wall	22 m²	4639	2.59 m³	Homogeneous	Gypsum Wall B
Basic Wall	22 m²	4724	2.61 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5986	5.38 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5999	5.39 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5878	4.45 m³	Homogeneous	Gypsum Wall B
Basic Wall	25 m²	5572	2.89 m³	Homogeneous	Gypsum Wall B
Basic Wall	25 m²	5572	2.89 m³	Homogeneous	Gypsum Wall B
Basic Wall	25 m²	5252	2.89 m³	Homogeneous	Gypsum Wall B
Basic Wall	27 m²	5828	4.39 m³	Homogeneous	Gypsum Wall B

Results
Data Integration in BIM



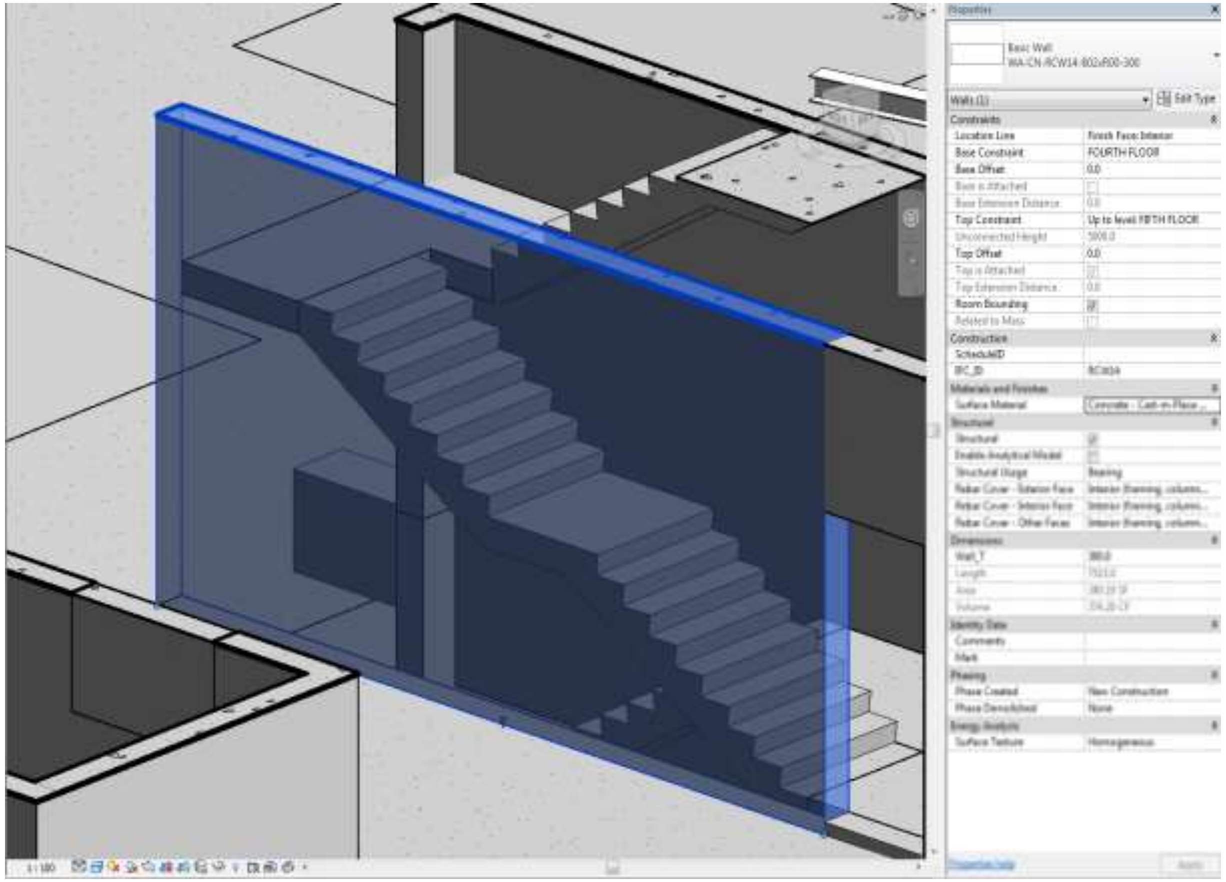
Results
Data Integration in BIM



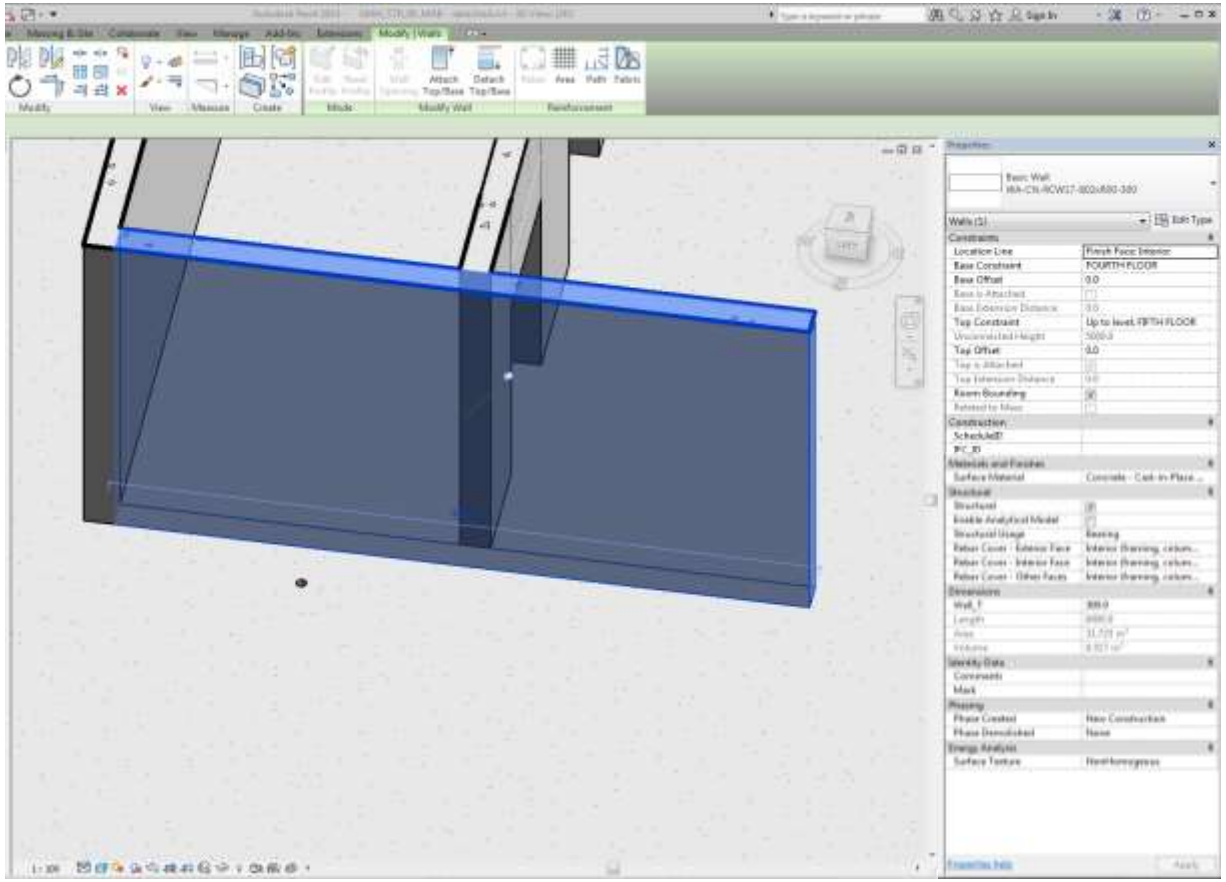
<Wall Schedule>

A	B	C	D	E	F
Family	Area	Length	Volume	Surface Texture	Surface Material
Basic Wall	21 m^2	2277	8.94 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	27 m^2	4450	8.14 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	24 m^2	4562	9.77 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	4900	8.79 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	30 m^2	4935	9.03 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	5500	8.74 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	33 m^2	6549	9.86 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	31 m^2	6771	9.44 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	6836	9.64 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	6900	9.52 m^3	NonHomogeous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	6900	9.52 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	7015	9.60 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	33 m^2	7673	9.89 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	27 m^2	8300	8.22 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	30 m^2	8300	8.96 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	27 m^2	8300	8.22 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	27 m^2	8300	8.22 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	27 m^2	8775	8.23 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	28 m^2	8800	8.26 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	9000	8.64 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	9000	8.59 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	9000	8.64 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	9000	9.72 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	28 m^2	9000	8.30 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	9000	9.72 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	9000	8.59 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	29 m^2	9000	8.57 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	30 m^2	9037	8.45 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	30 m^2	9300	8.93 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	32 m^2	9350	9.55 m^3	Homogeneous	Concrete - Cast-in-Place Concrete
Basic Wall	31 m^2	9350	9.26 m^3	Homogeneous	Concrete - Cast-in-Place Concrete

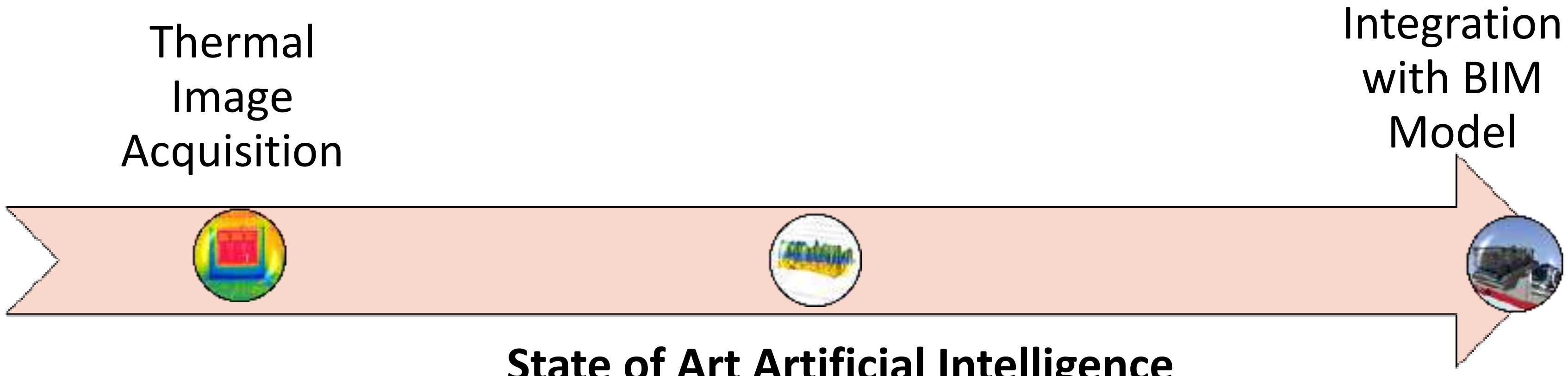
Results
Data Integration in BIM



Results
Data Integration in BIM



Conclusions



State of Art Artificial Intelligence

- Feature Extraction (Interior Walls)
- Data Analysis
- Testing and Validation

The proposed method used thermal infrared sensing to capture thermal images of the interior walls of an existing building. These images were then processed, and only wall features were extracted using a texture feature extraction algorithm. The resulted sub-images were then transformed into temperature values at each pixel of the interior walls.

Conclusions

Thermal Image Acquisition

Integration with BIM Model

State of Art Artificial Intelligence

- Feature Extraction (Interior Walls)
- Data Analysis
- Testing and Validation

A statistical correlations between the mean and standard deviation of interior gypsum and concrete were obtained through a Monte Carlo simulation approach.

The extracted texture and material information were then integrated in the BIM Model.

Conclusions

Texture Rich BIM models can be used in **LIVE** assessment of building conditions in relation to energy efficiency and water and waste systems leaks.