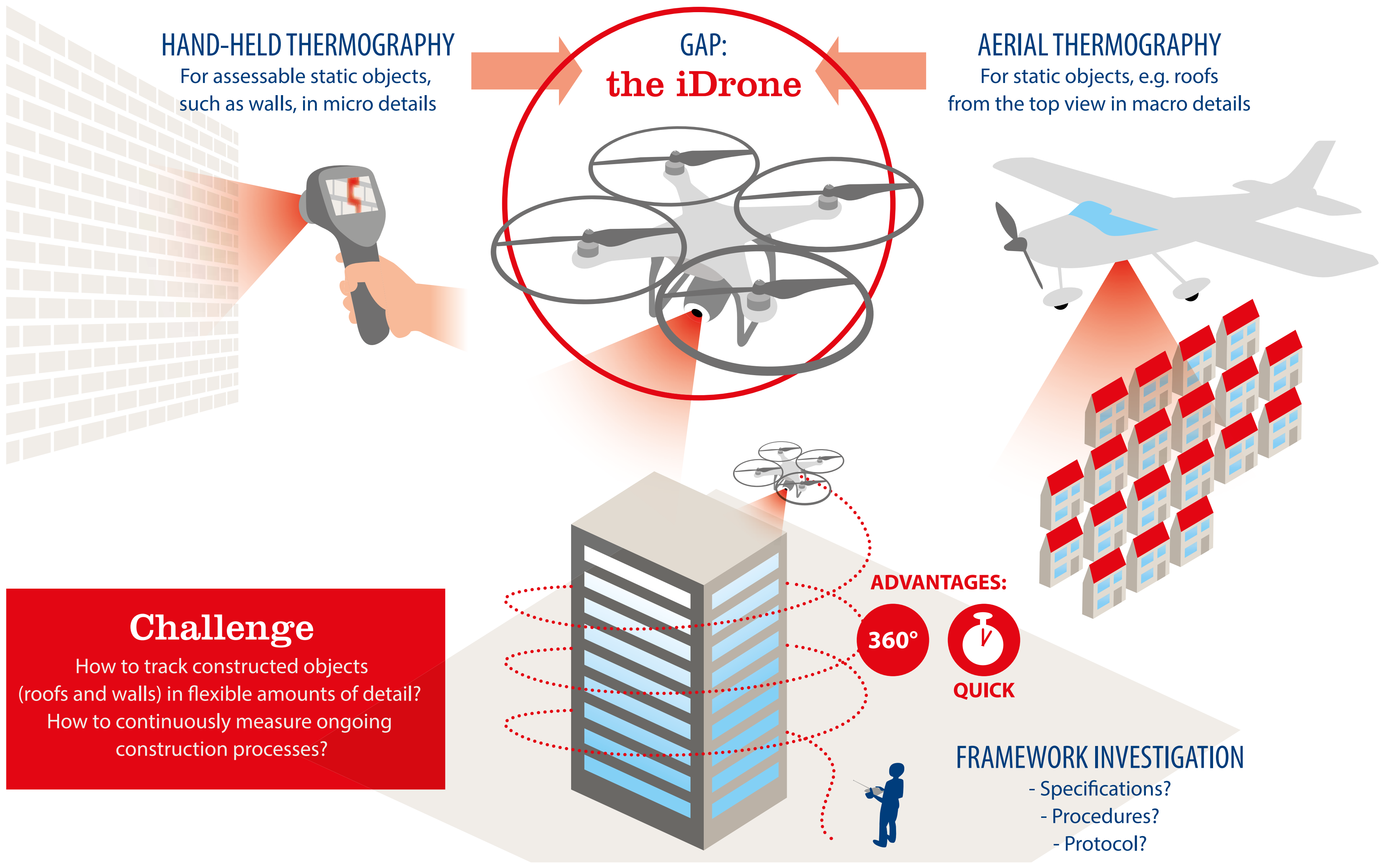
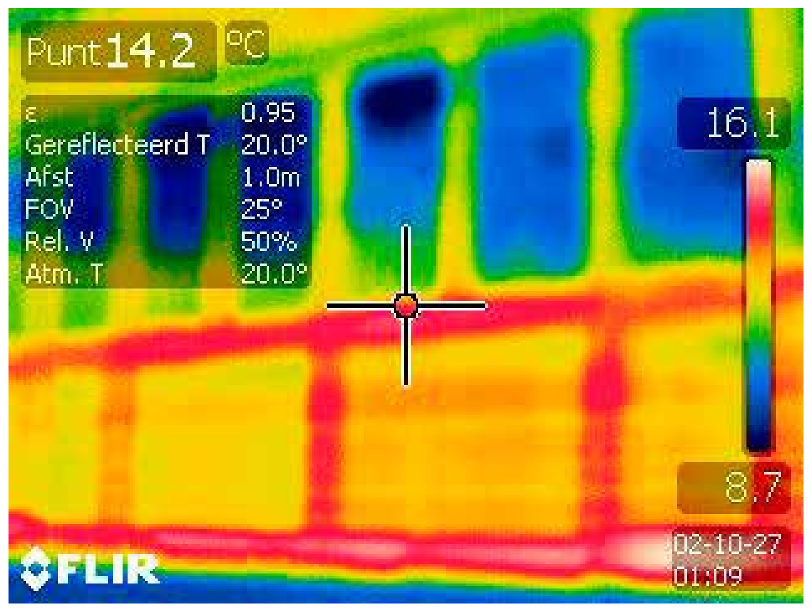
the missing link between micro and macro temperature mapping



Although many consider drones to be toys, multiple industries, such as the agriculture and mining industry, already know what advantages professional Unmanned Aerial Vehicles (UAVs) can offer. However, many companies in the construction industry do not seem to be familiar yet with the possible advantages of UAVs for their projects. In our 3TU Lighthouse project "Throw in the I-drone" we, the University of Twente, Delft University of Technology, HeightTech and BeemFlights, would like to make the construction industry aware of the possibilities UAVs have by demonstrating possible usages, by providing a protocol on how to use them and by simplifying the interpretation of data collected. Especially, the use of UAVs with an infrared camera will have our attention, because these systems can help in improving the energy performance of buildings reducing their environmental impact.



The gap: mesa scale temperature mapping
Thermography enables us to distinguish surfaces with different temperatures. Temperature data from infrared cameras can, for instance, pinpoint flaws in the thermal shell of buildings or electric problems in the meter cup board. The application of thermography on buildings is already a well-known practice. Unfortunately, this process is tedious and time consuming. On the other hand, large-scale airborne temperature mapping is both applicable and useful to document temperature signatures on the scale of whole suburbs at once. Still, that method is expensive and less controllable. As a result, these micro- and macro-scale of temperature mapping solutions help specific niches, while the intermediate mesa-scale stays underexplored.

Unmanned Aerial Vehicles (UAVs) with an infrared camera can help in improving the energy performance of buildings reducing their environmental impact.

The challenge: showing UAVs with IR to the construction industry
The University of Twente, Delft University of Technology, HeightTech and BeemFlights want to collaboratively challenge the current rules of temperature mapping by exploring this mesa-scale. We target to provide the missing link for the micro to macro temperature mapping continuum. Specifically, we aim to leverage current advances in IR-technologies and remote control Unmanned Aerial Vehicles (UAVs) to fill this gap by utilizing an "i-drone". The versatility of a UAV combined with enhanced IR vision enables new innovative type of temperature mapping, not available on micro and macro level.
This challenge has not widely been taken up by the construction industry, due to the risk of failing to repay the costs of the equipment. We expect it to open new horizons and enrich a number of practices. Among other tasks, the UAV will be very useful in monitoring building processes, studying the thermal losses of roof-systems, malfunctioning photovoltaic panels and for the inspection regarding building regulation. We will test the combination of UAV and IR cameras for constructions in use, e.g. dwellings, industrial buildings, and/or office buildings.

The results: research and knowledge valorisation
Our first efforts resulted in great footage to support our research and external communication. With the help of an UAV with a conventional camera a teaser was made to show the opportunities drones can offer in the construction industry when equipped with an infrared camera. Meanwhile, it was possible to establish a collaboration with drone manufacturer HeightTech. Secondly, a literature study by means of a capita selecta by a master student was conducted on thermography, UAVs and the combination of both providing insights in the current fields of knowledge.
Thirdly, as part of a bachelor thesis assignment a questionnaire was composed and interviews were taken among construction companies, facility managers and building advisors to find out what solutions an UAV could offer, enabling us to assess the potential impact of utilizing drones in the construction industry.
More technical elements in our research project, a fourth step, were focusing on how data is being collected by an infrared camera and how photovoltaic systems can be inspected with the help of an infrared camera.

We target to provide the missing link for the micro to macro temperature mapping continuum.

The future: testing and follow-ups
Currently, we are studying how to integrate the data obtained by the UAV and the output of data analysis into standard automated assessment procedures, reducing the amount of time normally needed to select, prepare and analyze the data. We are also developing a flight protocol. We plan to test our protocol for a building in use and a photovoltaic system by the end of February 2016. Last but not least, a follow up of the i-drone project is being discussed with companies in the field. It seems that multiple challenges still need to be overcome, before the construction industry and buildings can benefit from the use of professional UAVs in their full potential. A continuation by means of a PDEng trajectory seems an appropriate next step.

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DOUBLEFACE TO DOUBLEFACE 2.0

The Lighthouse DoubleFace project aimed at designing and prototyping an adjustable translucent modular system featuring thermal insulation and thermal absorption in a calibrated manner, which is adjustable according to different heat loads during summer- and wintertime. The output consisted of a proof of concept, a series of performance simulations and measurement and a prototype of an adjustable thermal mass system based on lightweight and translucent materials: phase-changing materials (PCM) for latent heat storage and translucent aerogel particles for thermal insulation.

Based on the results of the Lighthouse DoubleFace project, the STW Research Through Design proposal DoubleFace2.0 was submitted. The proposal was awarded and the project will run for 2 years starting from 2016. The research will focus on a specific demonstrator, using novel production techniques, like 3D printing, to explore their potential for creating high quality translucent and highly performative products. The approach is unique in that it aims for a system with high levels of adjustability to the specific conditions at hand and in which the functioning will be part of the identity of the product. This latter aim will be realized by a.o. the adjustability and shape of the system and by the materials that have a changing appearance depending on their physical state (solid or liquid). While dealing with the use of engineering performances as principles to trigger design creativity, ultimately, this research will result in a set of design concepts and in general knowledge on thermal performances.

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ENERGY EFFICIENT FAÇADE LIGHTING
Sculpture the façade with optical fibres

This project investigated the design of an energy-efficient lighting solution for highlighting architectural details of façades based on optical fibres. The project team consisted of members from the TU/e Building Lighting group, the TU Delft group Architectural Engineering + Technology, and the industrial partner BL Innovative Lighting from Canada. The lighting system has been tested for its photometric characteristics and was demonstrated in a pilot demonstration to showcase the suitability of this solution for façade lighting.

What happened after the completion of this project?
The project has received national and international recognition. Besides the successful demonstration at the Utrecht Bouwbeurs in February 2015, a project overview is published in the magazine of the Building Physics and Services (BPS) study association 'INSide Information', and the results are distributed to the members of the Plastic Optical Fiber Trade Organization (POFTO). The Canadian project partner BL Innovative Lighting was pleased with the overall results. The measurements proved that the system performs really well. The company is currently transforming the prototype into a product. The knowledge and experience gained in/during this 3TU.Bouw Lighthouse project has provided useful input for further product design. At the time of writing the company awaits the results from product safety testing. BL Innovative Lighting is eager to introduce the product to the market and considers showcasing it at European, Asian, and North American trade shows.

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LIGHTHOUSE PROJECTS 2014 UPDATE

IMPENETRABLE INFILTRATION; A SHORT REFLECTION

In 2014 "Impenetrable Infiltration" became part of the first edition of 3TU lighthouse projects. In this project the University of Twente, Eindhoven University of Technology and SelektHuis had the collaborative aim to improve the understanding of the air tightness of buildings by assessing the variables that have an impact on the infiltration rate of a building.
Due to the provided grant, it was possible to purchase equipment to conduct blower door tests. This equipment was used to measure the airtightness of several new detached houses. The project also resulted in two master projects, of which one was already completed. The results of a literature study and our research in the field were put down in two professional publications in TVVL Magazine.
Although we were able to collect and analyse 300 blower door test reports, this number was still too small to draw clear conclusions regarding what building characteristics are exactly related to airtightness. However, the current ongoing collaboration with SelektHuis and NBVL makes us believe that the future will bring more insights.

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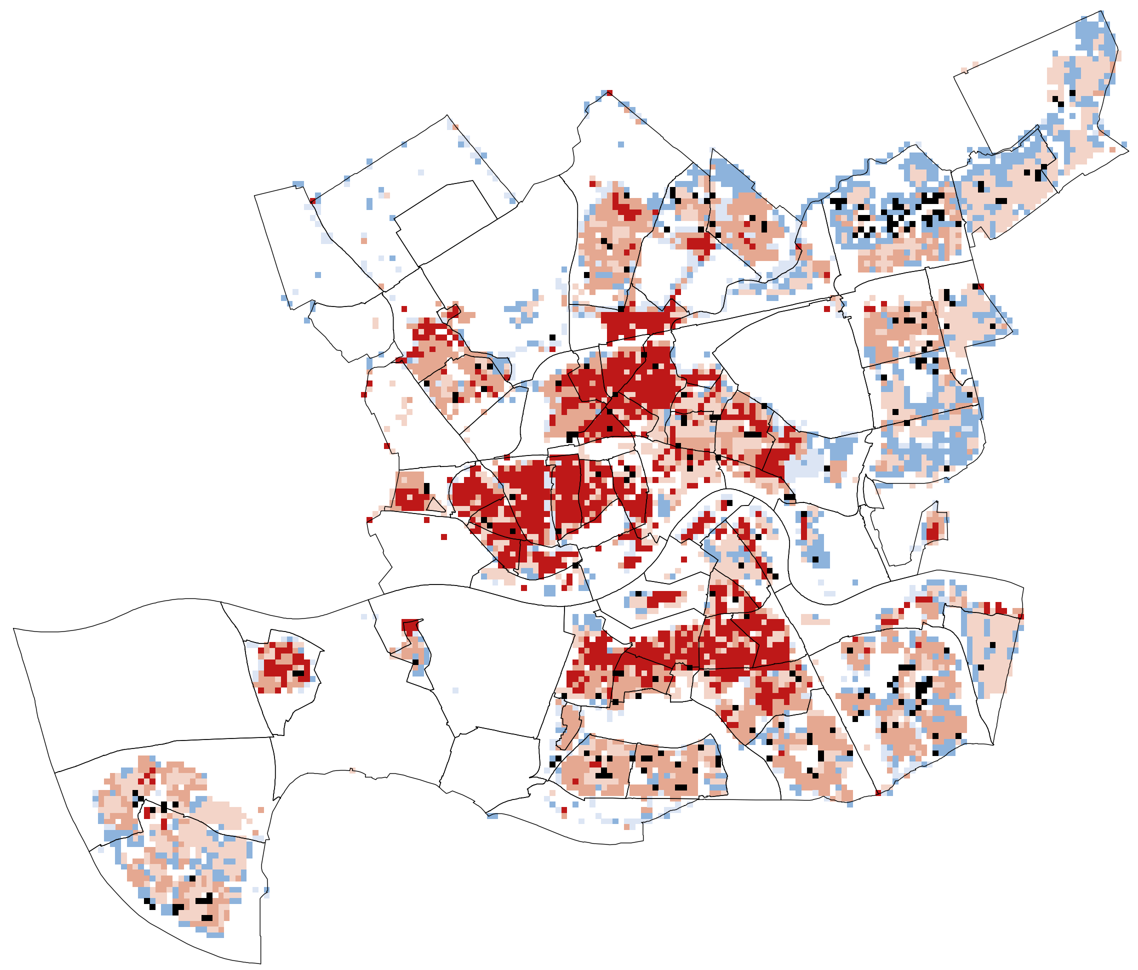
SENSING HOTTERDAM



The aim of the Sensing Hotterdam project was to gain a better understanding of urban heat in Rotterdam. Heat was measured with sensors in homes and outdoors while the surface energy balance was modelled as well. Social and physical features of the city were identified in detail with the help of satellite images, GIS and 3D models.
The project produced two heat maps, an atlas of underlying data and a set of adaptation measures which, when combined, will make the city of Rotterdam and its inhabitants more aware and less vulnerable to heat wave-related health effects.
In different ways, the pre-war districts of the city warmer and more vulnerable than are other areas of Rotterdam. Homes seem to have their own dynamics, in which the house's age plays a role.
The above-average mortality of those aged 75 and over during the July 2006 heat wave in Rotterdam can be easily explained on the basis of a) the concentration of people in this age group, b) the age of the homes they live in, and c) the sum of sensible heat and ground heat flux.
A varying mix of impervious surfaces, surface water, foliage, building envelopes and shade make one area or district warmer than another. Adaptation measures are in the hands of residents, home owners and the local council alike, and relate to changing behaviour, physical measures for homes, and urban design respectively.
A follow-up project for the city of The Hague will be kicked off in the summer of 2016 and will measure urban temperatures for the duration of three years.

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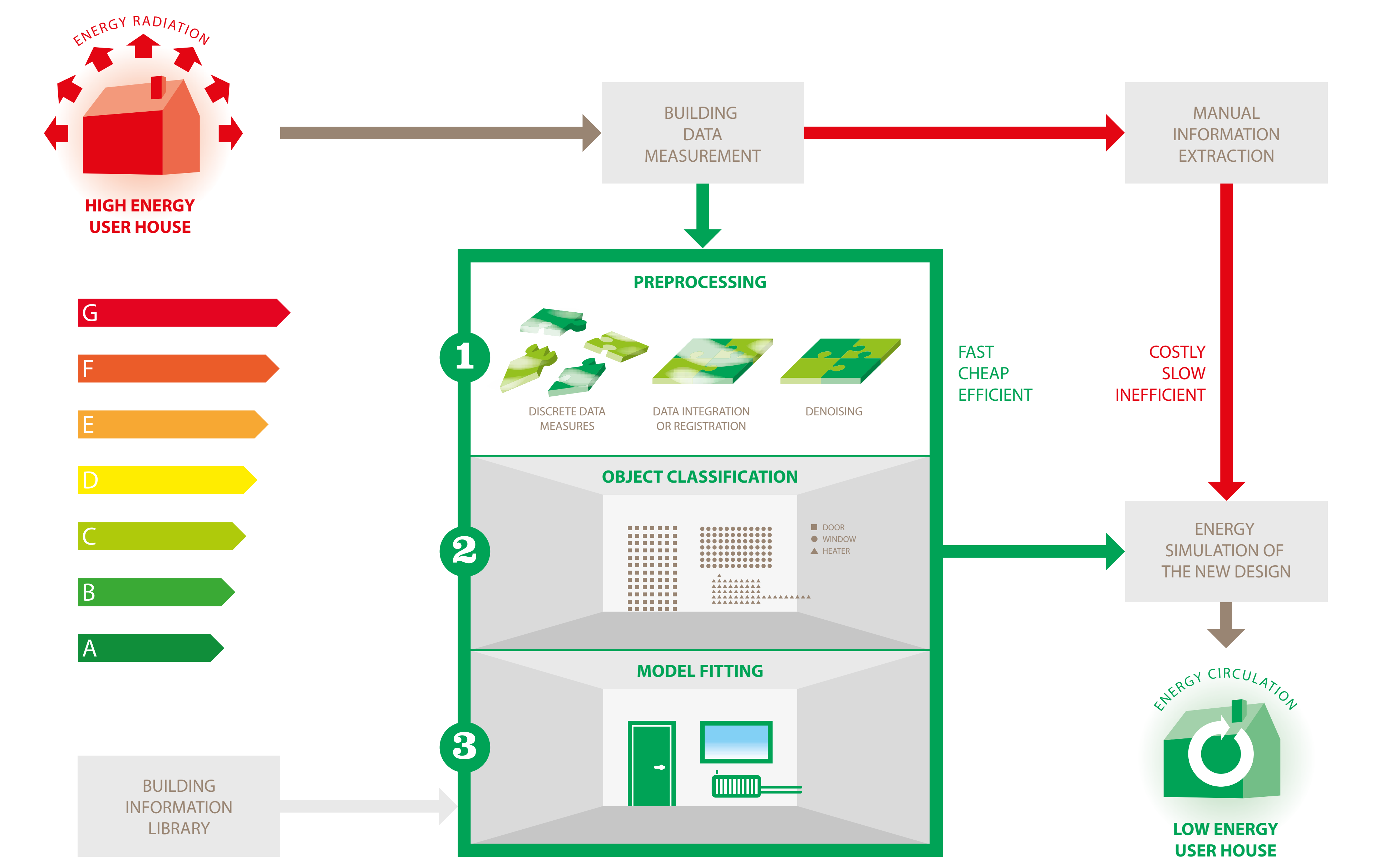
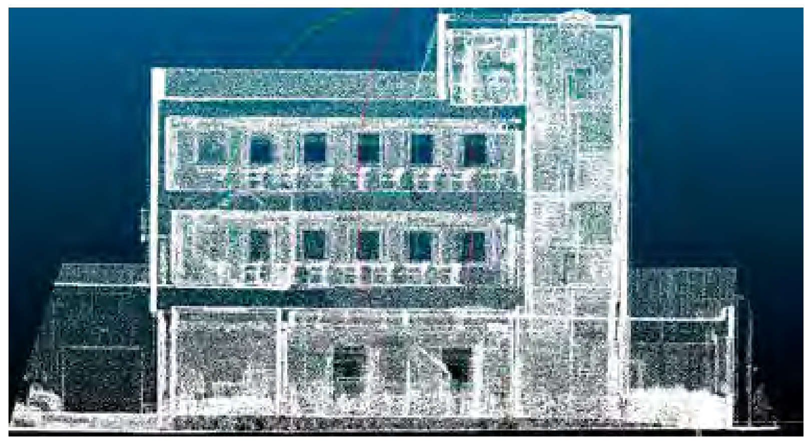
GEOMETRIC INFORMATION GENERATOR PDENG

automated 3D object information for energy simulation models



Renovation of existing buildings is known as an essential stage in reduction of the energy losses. A critical part of this process is simulation of energy usage based on geometric reconstruction of the building. Following many research projects focused on parameterizing the energy usage, various energy modeling methods were developed during the last decade. However qualified simulations highly depend on external geometric information of the building.
On the other hand, by development of the accurate 3D measurement tools such as laser scanners, the industry is highly eager to use this technology for innovative solution. Architectures, engineers and constructors were the early users of laser scanner products. But the application of this technology still does not meet the increasing industrial demands. The automation of 3D information extraction from laser point cloud and object detection tasks are still significant challenges of industry.
The aim of this project is designing a platform through which required geometric information can be efficiently generated to support energy simulation software. Developing a reliable procedure which extracts required information from measured data and delivers them to a standard energy modeling system is the main purpose of the project. Reaching to this point is highly beneficial both in short and long term. Energy labels for existing buildings are an urgent demand of authorities. Having a functional application to speed up energy simulation and energy label generation would be an early achievement of this project. In addition, methodological development of such a system would have a significant contribution in the as-built modeling research field



Expected outcomes

Current renovation procedure for energy efficiency is too slow and expensive and is not covering market demand. One of the bottlenecks is having a reliable 3D as-built model to run the energy simulation. However 3D modeling is a wide field in science with various methods and standards. Energy simulation software, such as Energy plus, requires general geometric information from indoor area of buildings. The coordination of heating zones, dimension and orientation of walls, position and shape of the openings, position and volume of energy sources are quite essential information for a reliable energy simulation. Therefore the expected outcome is an efficient platform which provides such information. Optimization between automation and accuracy for efficient energy simulation is the main target of this platform. Nowadays laser scanners are frequently used to provide dense as-built measurements. However the cost of modeling is often more than the measurement. Following algorithm describes an easy-to-use procedure which leads to creation of input file enriched by the geometric information for Energy Plus software. This procedure is designed to tackle the complexity of dealing with laser data, reducing uncertainty in calculations and avoiding unnecessary details.

The platform and the functional sections

The user can operate the platform through an interface (Figure 1). Push buttons, selection from the list and simple mouse clicks are all user efforts to interact with the program. Users can track the procedure through some illustrations and apply required changes. Functional sections are illustrated in Figure 2 and are explained in following subsections.

File input and floor detection

The Point cloud of a building can be uploaded as a text file to the system. At the beginning the point cloud does not have any structure. In this part histogram matching analysis is used to divide the point cloud to a number of levels. For this aim Z value of all points are used to generate a histogram. Some knowledge based conditions is employed to automate the process. For instance in the histogram, a minimum between two maximums (the ceiling points from previous story and the floor points from the next story) is considered as a clue to draw a division line. Or a condition of at least 3m distance between division lines is also considered to avoid wrong detections. Then the points of different stories are labeled.

This procedure is designed to tackle the complexity of dealing with laser data, reducing uncertainty in calculations and avoiding unnecessary details.

Segmentation of level points

A typical story is composed of a floor, a ceiling and some walls. In the most cases the floor and the ceiling are horizontal objects and the walls and their attached objects (doors and windows) are vertical. In this section, an algorithm is used to differentiate the floor and ceiling points from the rest of the points. The user can select a story to recall corresponding points. Ceiling points and floor points of the selected story are detected and labeled through a plane fitting function.

Wall extraction

The aim of this section is recognition of wall models. This is an essential step because the orientation of walls and their dimensions are very important information for energy simulation. Instead of the common methods which is based on plane detection in 3D space, 3D points are projected on XY plane as a main source of wall detection. This strategy brought some computational advantages. After some successive computations (mentioned in the flowchart of figure 2), main walls and their attributes are estimated.

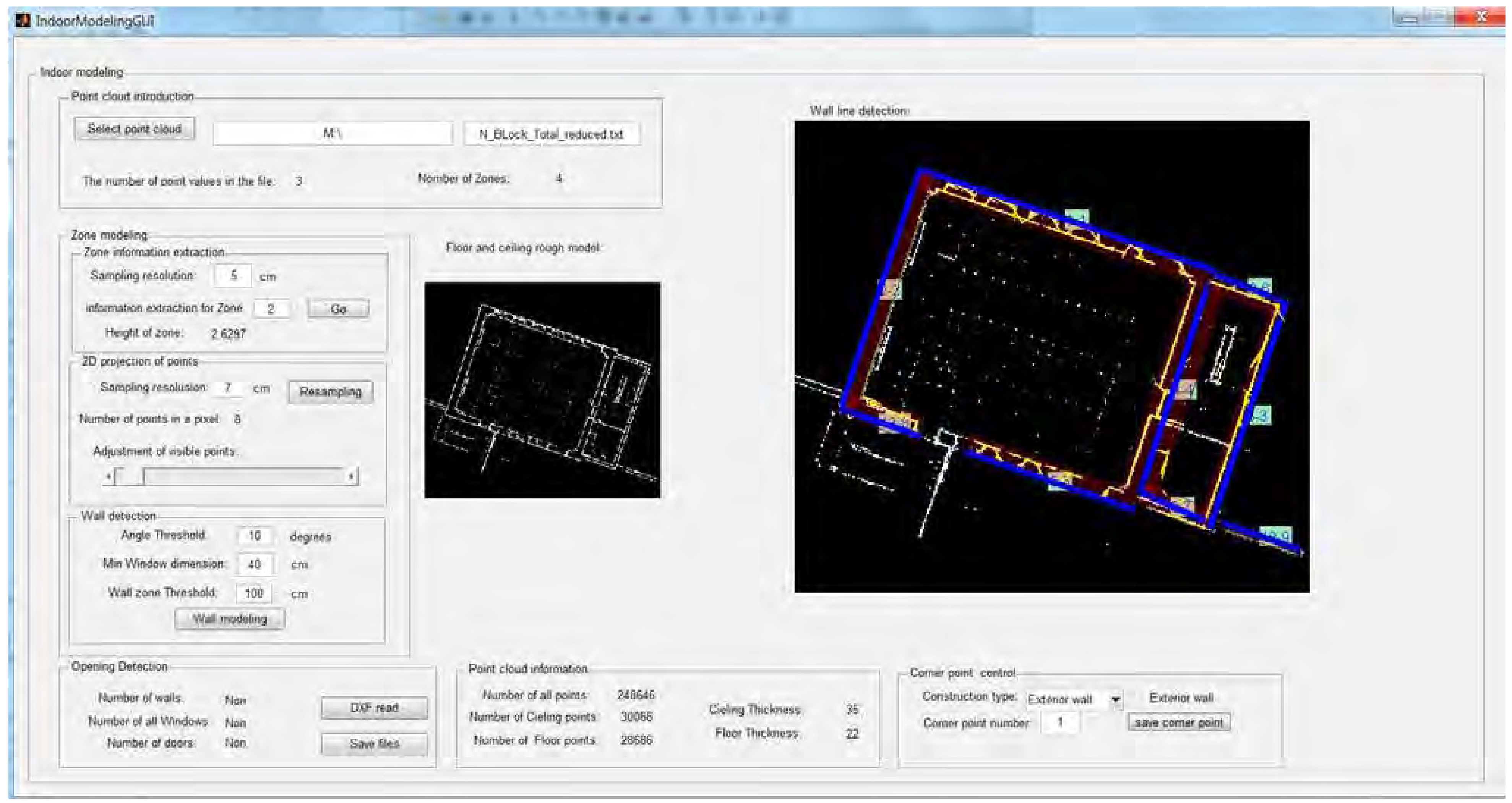


Figure 1: The platform interface

Figure 2: The flowchart of the program.

Openings extraction

Detection of empty spaces on the wall is the main clue of automatic window detection. The idea is that laser points are more dense and uniform on wall area. While glass windows are appeared as holes in point cloud. As another clue, windows with curtain or closed doors are appeared as a slight intrusion or extrusion in the dominant wall plane.

Verification and labeling

Extracted information needs to be controlled and verified by the user. For this reason a user-friendly section is designed. The results of automatic object detection are represented to the user through the interface. The user is enabled to apply some corrections with simple efforts such as mouse clicks and selection from a list. This information finally is combined with automatic driven information.

Save in Energy plus format

Verified information has to be transformed to a format which is readable for Energy plus. A sample txt file is used for this aim. Geometric information is added to the end of this file and saved in a separate name.

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