

AUGMENTED REALITY SUPPORTING THE PLANNING PROCESSES IN PV PLANTS

Franz Baumgartner^{*1}, Fabian Carigiet¹, Philipp Staiger¹, Benjamin Bachmann², Fredrik Gundelsweiler²

¹ZHAW, Zurich University of Applied Sciences, School of Engineering, IEFME MEA
www.zhaw.ch/~bauf, Technikumstr. 9, CH-8401 Winterthur, Switzerland; *phone: +41 58 934 72 32; email: bauf@zhaw.ch
²Zühlke Engineering AG, Zürcherstrasse 39j, CH-8952 Zurich, Switzerland

ABSTRACT: For small PV installations on single family houses in Switzerland, the costs for planning and administrative work is about the same than the PV module costs leading to new challenges for optimizing these relevant sector of BOS Balance of System costs. The HoloLens 2, an augmented reality (AR) device, was used to measure the geometry of the roofs followed by a design approach of arranging virtually the PV modules on the roof in a semi-automated and interactive approach. Typical measurement uncertainties of two centimetre were reached at distances of about 10 meters. The planner on the roof can choose between different PV module products and mounting components for example, for South or East/West configuration. The automatic module arrangement is based on the selected degree of shading losses from the HoloLens2 menu, which takes the measured shading obstacles and railing on the roof into account and thus the available area to place the PV module is limited. Finally, an offer is produced by the HoloLens 2 to be handed over to the customer a few minutes after performing the measurement. The next steps to further develop the tool is to integrate an ordering process of the bill of materials of the PV plant to save time and costs for the planner. Other administrative tasks and forms which must be fully filed to get the permission to build the PV plant need to be automated. Finally, the plant approval qualification test will also be supported using AR as a relevant goal for the next development steps in the project.

Keywords: PV plant, planning, geometry measurement, costs, Shading, BOS

1 INTRODUCTION

Today in most of the PV markets worldwide the costs share of PV modules plus inverter is lower than the rest of BOS costs of a plant. [1] This trend is ongoing since decades and is still accelerated by the cost reduction due to industrial production of modules and inverters.[2] In Switzerland the purchase of the PV modules accounting for one fifth of the total costs of a 5kW PV installation on a single family house. This is in the same range than the costs for PV planning including the up to 15 hours of administrative work to get all the needed permits. Using AR to facilitate these PV planning processes is the goal of the presented joint project to reduce total PV electricity costs.[4]

In other fields AR demonstrated successfully the measurement performance [5] the cost reduction in measurement at the customer site combined with planning and integrating it in an automatic ordering process of the individual parts. One of these examples was realised by our project partner with the chair lift tool and project. [6]

2 AR MEASUREMENT TOOL

The HoloLens 2 was officially presented in Feb. 2019 in Barcelona at the MWC (Mobile World Congress). Historically, the Kinect sensor technology has continued to develop over four versions:

- Kinect Sensor 1 (2005): Xbox 360: developed for the detection of movements and human-computer interaction, here especially for the detection of gestures and the human skeleton based on the interaction requirements of games.
- Kinect Sensor 2 (2013): Xbox One: for version 2, tracking and detection have been further improved.
- Kinect Sensor 3 (2015): HoloLens: special development of the Kinect sensor for the requirements of the HoloLens. Above all, these are low power consumption and very good

depth recognition, as well as gesture recognition and spatial mapping.

- Kinect Sensor 4 (2019): HoloLens 2: Development of own sensor by Microsoft, which is also sold as standalone device, and which can be connected to other sensors to form an array. This development is accompanied by a significant improvement in the depth camera through the use of ToF (Time of Flight). [7]

The requirement and today used technologies of measurement of the geometry of the roof is shown in Fig. 1. The potential benefit of the HoloLens is to use only one device and tool for most of the PV planning tasks.

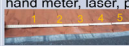





Technology	Measure Geometry & check roof quality	PV Plant Design	Order comp. Workflow
Traditional	hand meter, laser, picture 	Several software PV planning tools 	Several companies
Flying objects	Drone 		Several companies
Augmented Reality	Hololens SolAR 	Hololens SolAR 	Hololens SolAR autom. Gener. bill of materials

Figure 1: Measurement technologies for the PV plant planning processes and workflow including the developed SolAR tool.

3 MEASUREMENT PROCEDURE

The HoloLens 2 realises when a new person wears the device and it automatically starts the calibration for the person's eyes. The implemented measuring procedure uses a hand ray method. This means a ray is pointing out of the knuckles of the middle finger towards the target area. When the ray crosses an automatically recognised plane, a circle will appear. This detected location can be stored by executing a small hand gesture e.g. by tapping the index finger to the thumb. This gesture is called air tap. After performing this procedure for a second point on the roof, the distance between the locations is measured. This is repeated until the whole roof is measured. The last point

is connected to the first point building a polygon on the roof.

A roof was measured using a measuring tape as well as the HoloLens 2. The resulting distances were compared to each other leading to a standard deviation between the two measurement techniques of 2 cm.

Several measuring tests under different weather condition showed that there is a need of improving this measuring procedure for very bright days in combination with reflecting surfaces or for obstacle with thin edges.

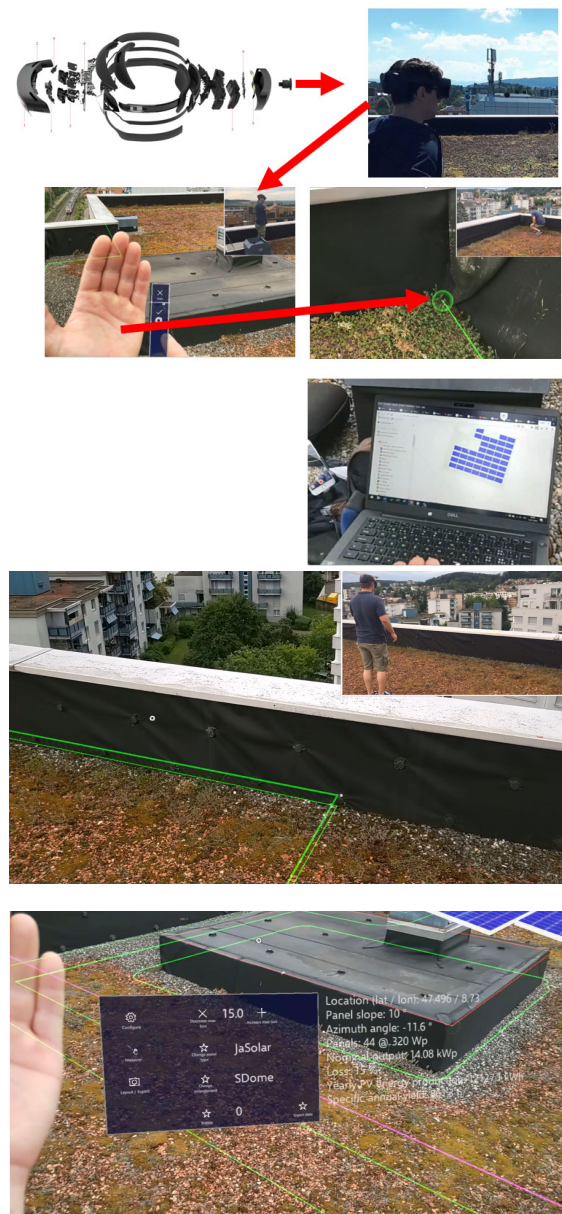


Figure 2: SolAR starts with the measurement tasks on the roof [3].

4 SolAR PLANNING PROCESSES

The planning process starts on the customer's roof and ends there too with an offer handed over to the customer. To reach that goal, several tasks needed to be developed and implemented into the augmented reality device. After starting the software prototype, following steps are going

to be performed:[3]

By pointing the palm towards the HoloLens 2, the menu will appear with the categories configure, measure and layout/export.

1. Configure:

1.a) The number of building floors is needed for determining the cable length. Therefore, the user clicks on the corresponding "add floor"-button in the menu.

1.b) With an external device e.g. a smartphone, the south direction will be determined. The orientation menu will show a yellow line, which can be moved by rotating the head left or right. This line has to be aligned with the south direction given by the external device. Finally, the air tap gesture will save this orientation.

2. Measure:

2.a) The whole roof area will be measured using the measurement procedure described in the previous chapter. This leads to a first active area for the PV planning displayed by a ground polygon.

2.b) The same procedure is repeated for the railing. Together with a maximal shading loss parameter, the active area is reduced by the areas where too much shading losses are present resulting in a second ground polygon.

2.c) All obstacles that lead to shading losses like a roof windows, a chimney are also measured and the additional restricted area for the PV modules is analysed.

3. Layout

3.a) The allowed shading losses (2 %, 5 %, 7.5 %, 10 % and 15 %) can be adjusted by pointing with the finger to the corresponding button. This will change the polygon form the step 2.b).

3.b) The PV modules are automatically oriented parallel to the longest roof edge. This orientation can be changed manually.

3.c) The user can choose the PV module type and the substructure mounting type e.g. 10° south or 10° east/west.

4. Export:

The annual yield is calculated based on the user inputs from step 1 to 3 and using the JRC PVGIS web API tool [8].

After pointing to the Export button, all data including the simulated yield as well the bill of material and costs are exported to a web server on the HoloLens 2. Thus, an offer can be downloaded and hand over to the customer on-site.



Figure 3 After completing measurement SolAR gives the planner the interactive choice to choose PV modules and mounting structures from the HoloLens menu [3].

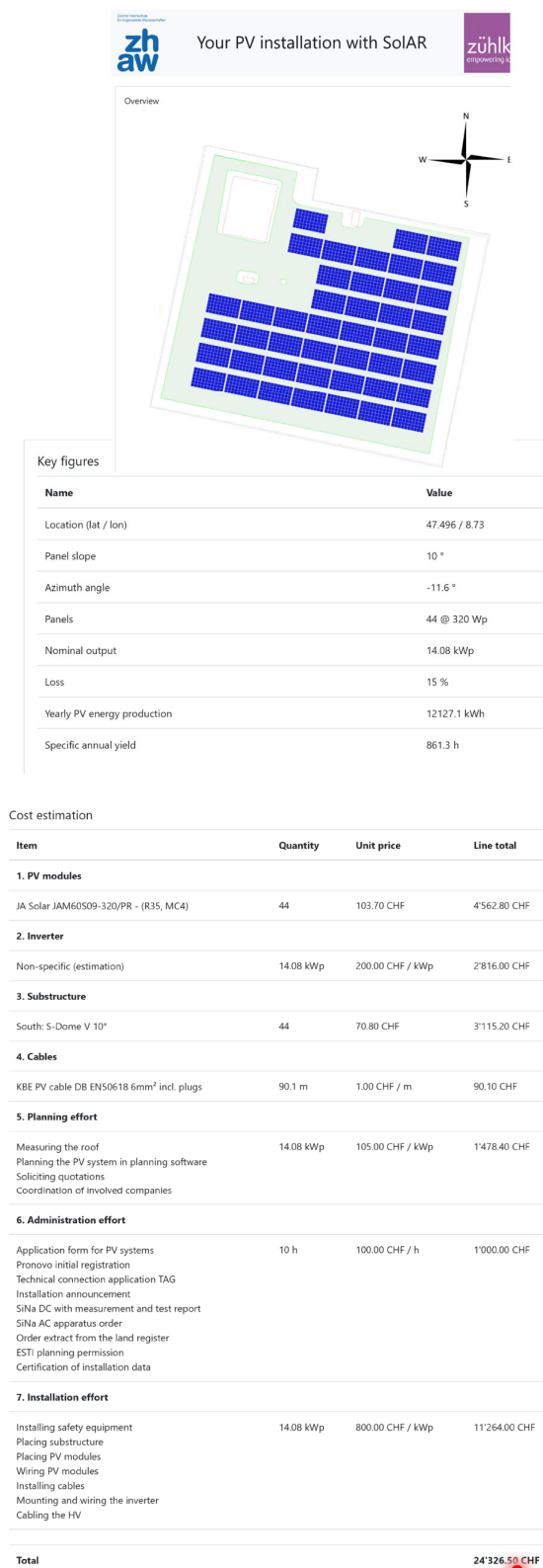


Figure 4 Resulted PDF printout of the SolAR measurement and planning process [3].

6 DISCUSSION AND OUTLOOK

The cost share of the PV modules in a PV system is decreasing every year. The remaining costs shares are becoming more important; for example, the planning cost

being one important factor for further total cost reduction. The proof of concept could be demonstrated with the first prototype software SolAR using augmented reality for the PV planning process.

This is just a first step towards the digitalisation of the PV planning process. A lot of work is going to be done in the next years including further improvements e.g. fall protection design, dimensioning of the PV inverter, automated ordering process, more detailed cost analysis, real-time yield simulations, and service task performed at the PV plant etc..

REFERENCES

- [1] IRENA Renewable Cost Database, 2019, www.irena.org/
- [2] Nicola Pearsall; The Performance of PV Systems; Chapter 5, F. Baumgartner: 2017; ISBN: 978-1-78242-354-6.
- [3] Video demonstration of the SolAR processes; <https://youtu.be/Fh5yggkVixw>
- [4] Philipp Staiger, ZHAW Master Project Work 2020
- [5] Hübner, Patrick et al. "Evaluation of HoloLens Tracking and Depth Sensing for Indoor Mapping Applications." *Sensors (Basel, Switzerland)* vol. 20,4 1021. 14 Feb. 2020, doi:10.3390/s20041021
- [6] Microsoft, HoloLinc: thyssenkrupp rolls out world's first mixed reality stairlift solution, allowing customers to visualise and customise products in their own homes, published online at <https://news.microsoft.com/europe/2018/10/22/holo-linc-thyssenkrupp-rolls-out-worlds-first-mixed-reality-stairlift-solution-allowing-customers-to-visualise-and-customise-products-in-their-own-homes/>, Oct. 2018 (last visited 10.09.2020)
- [7] Details on the sensors of the Kinect Version 4 are officially available at <https://developer.microsoft.com/en-us/perception> and in the presentation by Satya Nadella at the Build Conference 2018 at https://youtu.be/B_BXmoTy61o. More technical information and details can be found in the video from the "Research Faculty Summit 2018" at <https://youtu.be/aa8DzmvLxus>. The following table summarizes the essential details of the HoloLens 2 sensors
- [8] PVGIS JRC https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP