Summary of the doctoral dissertation of M.Sc. Eng. Jarosław Fastowicz entitled “Vision-based quality assessment of 3D prints” in the form of a collection of thematically related scientific articles

In recent years, interest in 3D printing has developed significantly. There are many devices on the market that operate in additive printing technology, as well as projects to build such a device. Low purchase and operating costs encourage more and more individual consumers to do so. The deposition of melted material has also found application in small-lot production as well as in the broadly understood Industry 4.0. During the onset of the SARS-CoV-2 coronavirus pandemic, the community of 3D printer users assisted the health service by printing helmets and components for medical equipment that were not available in these difficult times.

An imperfection of 3D printers available on the consumer market is still the problem influencing the quality and reliability of the 3D printing process. The most popular devices for additive printing with a consumable material - filament in the form of a line wound on a spool - are still one of the most unreliable printing methods, which is caused by many factors. Considering the nature of the printing process, it would be advisable to determine whether it is worth continuing the time-consuming procedure or stopping it. Often the causes of print quality problems do not lie with the device or the user, but with the material. A device that has been properly calibrated and regularly maintained should not affect the print quality, however, small contaminants in the filament may clog the head and cause "dry printing". In such a situation, continuing the process may even be dangerous due to the high temperatures reached by the printer’s head and printing bed. Interrupting the incremental printing process during such a failure can increase security, but it also saves money. There are also frequent problems with printing, where the phenomenon of damage on the printed object has a different degree of gradation, from small inclusions to very significant losses. The possibility of aesthetic evaluation of such a 3D print and possibly the interruption and removal of the problem by the user also saves time and money.

The presented collection of publications, constituting a doctoral dissertation, presents an approach to examining the quality of 3D prints in terms of aesthetics with the help of an automatic visual assessment of the surface quality of the printed object. The key assumption was to use various types of vision methods to classify a given sample while maintaining the lowest possible cost of implementing algorithms for assessing 3D prints. In the first steps, the work was based on the analysis of 2D scans of the prepared samples. It was caused by the need to verify individual image processing and analysis algorithms in terms of their possible use for the quality assessment of 3D printed surfaces. Images and video sequences captured by the camera are affected by additional disturbances, while the 2D scanner ensures even illumination of the element on the entire scanned surface. The research focused on 3 main directions of development, assuming the use and modification of known methods based on texture quality assessment, general-purpose image quality metrics, and image entropy.

As part of the research work, a database of 3D prints with different surface quality was prepared. The prepared samples had the shape of a cuboid with dimensions of 40×4×40 mm, and for each sample, the tests of the surfaces of both sides were carried out independently. As the research progressed, the database was gradually developed and enriched with new samples, also made of other types of material. In the initial stage, the database contained the results of the subjective assessment carried out in the form of an expert classification.

During one of the last stages of work, the images captured with the camera were used to verify the proposed algorithms. The obtained results made it possible to confirm the thesis about the possibility of an effective visual assessment of the quality of 3D printing *in situ*. The sample database was enriched with subjective assessments obtained from a group of approximately 90 respondents. The samples were assessed by independent observers in terms of their individual aesthetic preferences, which showed compliance with the previously presented expert classification of the same samples. The obtained average subjective ratings were used to analyse individual algorithms and – in the last phase of work – to verify the hybrid metrics, consisting of a nonlinear combination of two or more methods that were less effective, proposed to improve the effectiveness of the objective assessment of a 3D print sample using visual methods.