Dotyczy rozprawy: Hybrydowa wizyjno-radiowa metoda wspomagania rozpoznawania i pozycjonowania komponentów inteligentnego środowiska domowego oparta na uczeniu maszynowym
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Streszczenie rozprawy w języku angielskim

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The digitalization of human environments is progressing, accompanied by the widespread creation of their digital representations. Three-dimensional models of buildings are increasingly employed, and their construction is based not only on professional spatial scanners but also on everyday devices such as action cameras or smartphones. Regardless of the data acquisition device, the developed models lack what is most important: the semantic meaning of their components. These are digital reproductions of reality, such as point clouds, yet devoid of useful information regarding the types and functions of their elements.

To fill this gap, this dissertation proposes a hybrid vision–radio method for supporting the recognition and positioning of components within a smart home environment, based on machine learning. This approach enables the recovery of lost semantics, attributing meaning to raw data and determining their functions. To achieve this, two branches of technologies were combined: radio-based positioning and computer vision enhanced by artificial intelligence. These were integrated into a hybrid method and subjected to extensive examination.

The dissertation discusses the entire development process of the proposed solution: from the analysis of the literature and current state of the art, through the design of prototypes and evaluation of their effectiveness, to the formulation of an original methodological approach and its testing. The work was conducted in a systematic manner, with each stage defining a specific problem, analysing proposed solutions, and validating their usefulness, particularly in industrial applications. The research began with a review of the literature, as well as market studies and user expectations. The derived insights guided the design of the first prototypes of both radio and vision systems. In the domain of radio systems, the research commenced with distance estimation studies, which provided insights into the performance and operating principles of Bluetooth Low Energy (BLE), Ultra-Wideband (UWB), and the Matter protocol. On this basis, two algorithms were developed: a general positioning algorithm, used to determine the rooms in which experiments were conducted (based on BLE), and a precise positioning algorithm, using UWB and trilateration to compute the coordinates of tracked objects. In the domain of vision systems, the work began with investigations into the performance of various generations of YOLO (You Only Look Once) object detectors on publicly available image datasets, followed by an analysis of the process of constructing custom datasets. An original algorithm was proposed for determining the optimal meridian for cutting a sphere during its projection onto a panoramic representation. Furthermore, the application of a depth estimator was examined for assessing distances to objects detected in panoramic images. The obtained results were combined with knowledge of spherical coordinate transformations and developed into a vision-based positioning method that determined the location of detected objects within the coordinate system of the device digitizing the environment. Finally, the synthesis of experimental results, methodological developments, and prototyped devices was achieved.

Extensive experimental evaluations confirmed a high degree of automation in recovering semantic meaning within raw digital models of monitored properties. In the constructed test environment, the application of the proposed hybrid method enabled the automatic detection of 62% of all components. Importantly, 95% of the detected objects were also spatially localized within a three-dimensional environment with an average precision of 71.8 cm. This enables an end user to locate even small-scale objects within a radius of less than one meter from the indicated point, irrespective of whether the target is an electronic device with embedded radio components or a purely passive, unpowered object. The proposed method can therefore be applied by a wide range of end users, both private and industrial. Its applications include a variety of resource-localization tasks, such as identifying office equipment requiring maintenance (e.g., air-conditioning units) or conducting asset inventory (e.g., fire extinguishers).