Practical technologies for Smart Shops

Unmanned shopping markets are completely self-service and self-checkout.

 The registering of bought products and their payments is monitored by distributed sensors, artificial intelligence, machine learning algorithms, and dedicated mobile applications. From the moment customers enter smart shops, their route, the products they browse, pick up, place in their baskets and replace on shelves is monitored. What customers are looking for is a just-walk-out experience. Meeting this customer preference requires the development of smart technologies that are unobtrusive, intuitive and extremely accurate. Balancing customer needs with cost-effective high-performance technologies, whilst at all times staying within GDPR regulations, is one of the great challenges facing the partners in the EU funded project MIMEX. MIMEX is approaching this through the thorough evaluation, development and fusing of state of the art solutions using complementary approaches. In smart shopping spaces, technologies must be: robust to line-of-sight occlusions, invariant to illumination changes, and they must be resilient to everyday activities like shop restocking and redressing, otherwise auto-purchasing mistakes could occur; inevitably lead to a decrease in shopper trust. Of equal importance is shop-manager acceptance as they demand very high levels of technological robustness and performance, combined with cost effectiveness and practicality. Absolute trust in product movement monitoring and auto-purchasing technologies is imperative for tasks like: stock supply scheduling and the detection of potential thefts.

In this first, of a two-part, article on technologies for smart stores, we will provide a brief overview of the three main approaches: weight sensors, radio-based solutions and computer vision, followed by a more detailed discussion about specific computer vision solutions. Weight-sensors are often placed inside smart shelves to detect the presence, or lack of, products placed upon them. They rely on strain-gauge load cells that exploit resistance variations in conductive wires or pressure sensors that exploit resistance variations in elastic materials doped with conductive particles (e.g., carbon/nanotubes). Radio-based solutions (e.g. RFID, NFC, UWB and Bluetooth) are commonly exploited in many retail scenarios, with each offering different detection ranges and unit costs. In all cases, markers/tags are attached to products and then one or multiple readers placed on or around smart shelves are exploited to detect their movements. Computer vision technologies feature heavily in many smart-market solutions as they are unobtrusive and they do not require the shopper or products to carry additional markers/hardware to make them work. They function by effectively spotting and tracking the unique visual-features/signatures of shop products, using metrics such as visual appearance (e.g. clothing/packaging colours, textures, etc.) and physical dimensions. However, the visual tracking of products in this way necessitates that all merchandise in a shop's inventory is firstly visually-digitised into a database. This can be a potential bottleneck, as the characterising/adding of new products is inherently non-trivial. MIMEX will approach this issue through the exploitation of recent advances in machine learning which will enable the faster training and adding of new products to a shop's e-inventory; reducing the product-training burden on shop owners, increasing MIMEX's attractiveness. In addition to tracking products, all shoppers also need to be followed as they move throughout the store to understand who picks up which products and places them in their bags/baskets. To achieve this, MIMEX is exploiting patented solutions coming from project partners that have been proved to be robust even in very crowded spaces. For both product and person tracking, a further issue that is delaying the widespread deployment of computer vision solutions in smart stores is their requirement for huge processing power. In MIMEX, recent developments in embedded and edge hardware are being exploited. This means that powerful computer vision algorithms can now be run both in on-board cameras, and also very close to cameras on shelf-processing edge-units. This advancement means that complex neural network models can be run in parallel on the same device, and the extra capacity means that resources can be shared across multiple shop shelves, reducing costs even further. Depth cameras with embedded processing, can also provide visual tracking solutions that help overcome line of sight occlusions and shadows. Depth cameras produce a high-level of tracking accuracy with only a single camera, thus potentially delivering more accurate customer engagement metrics. However, networks of overlapping and low-cost monocular cameras are still more cost-effective and if calibrated correctly can ensure a better multi-viewpoint coverage at a lower cost. Fisheye lenses can also be inserted into visual tracking networks, and as they offer ultra-wide-angle panoramic coverage, they can cover confined spaces and corners. To non-invasively monitor body temperature, a considerable worry in COVID-19 times, thermal cameras can also be integrated into smart-camera systems, instructing automated turnstiles to deny access to people that pose a potential risk to customers already shopping. In MIMEX we are exploring all of these camera options in order to find an optimal balance between cost and performance.

To gain valuable insights about what is happening in smart shops at a global scale, one individual type of product/shopper tracking technology is insufficient. MIMEX is therefore creating a machine-learning sensor fusion module that will reduce ambiguities, and add robustness to the shopping experience. To validate our approach and choice of technologies, MIMEX will evaluate usability and practicality for a wide range of stakeholders, ranging from the sensor installation process for shop fitters, to the interface responsiveness for shoppers. These practical metrics will come from experiences with our first prototype installed in Trento, Italy (Autumn 2021) and then from two subsequent pilots installed in Spain and Turkey (Spring 2022).