BlueBio SMARTCHAIN Project

Robotic manipulation of food objects

Research Findings Brief

September 2024

Robotic automation

SMARTCHAIN focuses on developing robotic automation solutions for manipulation of food/fish objects.

These efforts aim to improve efficiency, sustainability, and competitiveness of producers/processors across the seafood supply chain.

Innovative approach

By integrating advanced perception and control mechanisms, the robot is capable of handling delicate, deformable objects with precision and care, ensuring minimal damage while optimizing efficiency.

Application of robotic manipulation in Food/Seafood

The growing demand for sustainable food production and handling has highlighted the necessity of robotic manipulation in the food and seafood industries. As global consumption of seafood rises, traditional manual processing methods struggle to meet the demand for efficiency, precision, and hygiene. Robotic automation offers a solution by enabling delicate yet consistent handling of soft, deformable objects like fish and seafood, which are difficult for humans to manipulate quickly and safely at scale.

Automation not only improves production efficiency and reduces labor costs but also minimizes food waste and ensures compliance with strict food safety standards. The integration of robotics into food handling presents a competitive advantage, aligning with the industry's focus on sustainability, resource optimization, and enhanced product quality (Misimi et al. 2018)[1].

The SMARTCHAIN project has addressed these challenges by developing a closed-loop, 4DoF robotic manipulation approach that enables both prehensile (grasping) and non-prehensile (non-grasping) manipulation for the gentle handling of food and seafood objects. This approach leverages RGB-D visual sensors and operates using both eye-in-hand and eye-to-hand configurations, allowing the robot to adapt its manipulation strategies dynamically based on real-time feedback.

By integrating advanced perception and control mechanisms, the robot is capable of handling delicate, deformable objects with precision and care, ensuring minimal damage while optimizing efficiency. This innovative approach addresses the industry's need for gentle and accurate manipulation while aligning with goals of sustainability, reduced waste, and enhanced food safety standards. Through its closed-loop control, the approach continuously refines its movements, contributing to the broader adoption of robotics in food processing and ensuring compliance with modern operational requirements.

[1] E. Misimi, A. Olofsson, A. Eilertsen, E.R. Øye, Robotic Handling of Food Objects by Robust LfD, IROS 2018. Doi: 10.1109/IROS.2018.8594368

Preliminary Findings

The preliminary findings of the project demonstrate the effective use of an RGB-D sensor in developing control strategies for both prehensile and non-prehensile manipulation (Figure 1).

For prehensile manipulation, the RGB-D sensor enables the robot to detect the object's shape, location, and pose in real-time. The robot then dynamically adapts its gripper's position and orientation at each iteration in a closed-loop manner, ensuring precision and accuracy throughout the task execution. Utilizing a velocity control mode, the robot leverages a visual servoing approach, which continuously adjusts the gripper's movement and its pose until a successful grasp is achieved. This ensures that the robot can handle objects of varying shapes and sizes with a high degree of flexibility and control.

For non-prehensile manipulation, the robot is controlled to place its gripper over the object and initiate a 4DoF pushing action to slide the object to its desired pose. This process is also performed in a closed-loop, with the robot monitoring and adjusting its actions based on real-time feedback from the RGB-D sensor until convergence is reached. By utilizing the same closed-loop control approach, both manipulation modalities—grasping and pushing—are executed with high accuracy, allowing the robot to perform complex manipulative tasks with minimal error. These initial findings underscore the versatility and adaptability of the developed strategies, highlighting the potential for efficient robotic manipulation of food objects in real-world applications.

Figure 1 4DoF robotic manipulation control scheme

Manipulation strategy

A closed-loop, 4DoF robotic manipulation approach enables both prehensile (grasping) and non-prehensile (non-grasping) manipulation for the gentle handling of food and seafood objects

Prehensile manipulation

RGB-D sensor enables the robot to detect the object's shape, location, and pose in real-time

Non- Prehensile manipulation

The robot is controlled to place its gripper over the object and initiate a 4DoF pushing action to slide the object to its desired pose

Robotic Automation – Recommendations

The preliminary findings highlight that there is a clear need for greater adaptability across the sector to ensure the successful adoption of robotic-based solutions in the food and seafood industries. This can be achieved through tighter collaboration between research and technology developers (RTD) and industry vendors to create flexible solutions that can be seamlessly integrated into any processing plant. Additionally, leveraging the growing access to data for training AI models [1] are crucial for enhancing learning and control strategies in robotic systems. In cases where data is scarce, the generation of synthetic data offers a powerful alternative for training models, with or without fine-tuning in real-world environments ensuring robust performance [2]. For achieving gentle manipulation, especially with delicate or deformable objects, it is essential to integrate visual and force control systems. This allows robots to adapt their interaction forces to the specific properties of each object, preventing quality degradation [3]. By combining prehensile and non-prehensile manipulation techniques, robots could deliver optimal results in a wide range of handling scenarios, enhancing product quality, efficiency, and competitiveness.

Key sources for further information

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Deliverables:

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- O.M. Pedersen, **E. Misimi**, F. Chaumette. Grasping Unknown Objects by Coupling Deep Reinforcement Learning, Generative Adversarial Networks, and Visual Servoing, ICRA, 2020. Doi: 10.1109/ICRA40945.2020.9197196

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2. S. Herland, K. Bach, **E. Misimi**. 6-DoF Closed-Loop Grasping with Reinforcement Learning. IEEE International Conference on Robotic Automation, ICRA 2024. Doi: 10.1109/ICRA57147.2024.10610080
3. A. Lillienskiold, R. Rahaf, P.R. Giordano, C. Pacchierotti, E. Misimi, Human-inspired Haptic-enabled Learning from Prehensile Move Demonstrations. IEEE Trans. System, Man, Cybernetics: Systems 2022. Doi: 10.1109/TSMC.2020.3046775

SMARTCHAIN – Smart solutions for advancing supply systems in blue bioeconomy value chains

https://bluebioeconomy.eu/smart-solutions-for-advancing-supply-systems-in-blue-bioeconomy-value-chains/
https://www.sintef.no/en/projects/2021/smartchain/

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