AI assisted Cobot potential for meat cutting procedures

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Objective: Primal cutting in the Danish pork meat production is made with automated cutting blades arranged with a fixed pose relative to the carcass. Adaptation to individual carcasses is only possible in the longitudinal direction. The imposed constraints leave a substantial need for manual trimming procedures to finalize e.g., a ham for dry cured products.

The objective is to demonstrate a primal cutting of the ham using an AI assisted industrial cobot and active cutting devices. The outcome will seek to quantify the yield benefit and the reduced need for manual aftertrimming in making the ham ready for dry curing.

Materials and Methods: The potential yield improvement is indicated on a small sample of Danish pig carcasses with the conventional primal cutting process as benchmark.

The cutting trajectory is predicted with a 50-layer CNN (ResNet50) network, trained on a few hundred carcasses with annotated landmarks on 3D images.

The Cobot is a KUKA iiwa LBR820 model, mounted on a movable, self-contained trolley, including fixed 3D camera, robot con- troller and interface computer. The work zone is surveyed by a PILZ SafetyEYE 3D camera safety system, relaxing the need for a fenced safety barrier, yet without compromising operators' safety working in the vicinity of the trolley.

The cobot is operated using a RoboDK-based interface and proprietary software written in Python. The work-zone is surveyed with Kinect Azure 3D camera and calibrated by moving a known sphere as an endof- arm tool by the cobot, between a selection of positions within the field of view of the Azure camera. The calibration approach is using the RGB image to identify the sphere and then isolating the sphere in the color-in-depth image followed by fitting a spherical shape of known size to the 3D point cloud followed by determination of its center. The transformation between the center and the reference TCP of the end-ofarm tool is optimized using the selected (Known) positions.

Using the optimized transformation any object position within the work-zone can be determined by the camera and described in the reference coordinate system of the KUKA cobot.

The cutting trajectory is annotated by an expert butcher by indicating four primary landmarks on the carcass sample. The annotations are made on 2D "color-in-depth" images in a CVAT environment using the DATUMARO file format to convert the annotations to training input to the ResNet50 models. The annotation is made in 2D by the expert and then the internal camera calibration coping for the angular and perspective difference between the two sensors of the Azure camera to give the total spatial information of the annotated landmarks in 3D space.

The trajectory for each carcass is made by morphing a generic trajectory, determined empirical, into the predicted trajectory from the ResNet50 model. The generic trajectory is generated using the RoboDK GUI interface, for planning the joint setting of the KUKA cobot to reduce the risk of singularities in any of the joint movements throughout the complete U-shaped trajectory.

To reduce the cutting forces imposed on the carcass a reciprocal knife is used as end-of-arm tool. An EFA PK25 pneumatic driver is mounted with a bespoke cutting blade. The blade includes a cutting part and a sawing part, the latter for handling the spinal bones.

Results and Discussion: The performed yield is documented and the challenges in assisting the cobot with 3D vision and AI modeling will be discussed.

The calibration accuracy is in the range of +/- 6mm for the estimated center of the calibration sphere when moved as end-of-arm tool in the work zone of the cobot. The accuracy may be improved using more points for the calibration procedure.

On top of the calibration accuracy, the model accuracy must be included to lead to the total trajectory quality of the cutting procedure. Accuracy requirements to trajectory is different for each of the annotated landmarks defining the cutting path. The highest ac- curacy is needed on landmarks at the spine joint to assist the planned cutting through the vertebral joint of interest. An optimized ResNet18 model for these (2) points only, leads to a model performance with a residual standard deviation in the range of 5 mm. The complete trajectory accuracy using the ResNet50 model is demonstrated to be in the range of 20mm. One reason for this performance is that the annotation noise from the expert butcher is higher for some of the landmarks compared to the spinal annotations due to anatomical features visible at the spinal vertebras.

Conclusion: The cutting trajectories made available with an AI assisted industrial cobot may open for automation of more delicate procedures in the boning rooms.

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