final report

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HookAssist 0.1 workshop summary report and proposed design changes for phase 3

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Contents

1 Document Overview

This document will provide a summary of the activities performed, and lessons learned during the Workshops that were carried out in Australia (Melbourne - NMIT, and Perth – Harvey Beef) in August and September of 2008, and clearly outlines the proposed modifications to the HookAssist that will be implemented during Phase 3 of the development of the HookAssist project, and will also specify those items that will not be addressed during Phase 3.
In addition this document captures all the comments/suggestions that were made during the Workshop by boners, industry experts, processing plant representatives, industry vendors, and system integrators.

2 Phase 3 Overview:

We propose that Phase 3 start by having a number of different beef boners test the HookAssist_0.1 developed during Phase 2 in a controlled environment in a plant (i.e. not on the production line) performing the tasks that it was designed to assist with. These include a range of boning operations, such as thin skirt, tenderloin, loin, h-bone, rump, knuckle, topside, silverside, and shank. The device should also be used to explore other beef processing operations that might be possible.
Once HookAssist_0.1 is tested Kinea Design together with MLA and industry experts will refine the set of requirements for the HookAssist_0.2 with the lessons learned and any other additional requirements that arise. These requirements will in turn guide the design and development of a HookAssist that is flexible enough to operate in a beef processing plant.
Following the design phase of the Kinea Design will manufacture two HookAssist_0.2 devices to be installed in two beef processing plants, for in-production line testing. This testing will further guide the design of a durable final product.

2.1 Objectives

- Test HookAssist_0.1 (developed in Phase 2) in a controlled environment in a beef processing plant in Australia; this task has been completed.
- With the lessons learned from using HookAssist_0.1 refine the design and make the modifications required for installation in a plant for in-production testing.
- Particular attention will be focused on:
    - gimbal geometry; waterproofing for washdown; safety; ceiling mounting; increase in pull force capability; hook handle, length, and profile; gimbal self-homing; chain tracking; hook-meat release; conversion to 415V-3phase power; serviceability; and reliability.
    - Build and assist in the installation of two HookAssist_0.2 unit in beef processing plant.

3 Workshop Summary

In August 2008, a demonstration of the HookAssist device was carried out at the Northern Melbourne Institute of TAFE, (Epping campus) to Australian beef and sheep processors and producers (Figure 1). During this week at NMIT the device was tried by a number of different boners as well as administrators, and industry experts. The device was used to perform the complete set of cuts on both hind and forequarters of a number of beef carcasses, as well as some boning tasks on sheep carcasses. The device proved to be flexible enough to carry out all

the tasks that were tried, these included: tenderloin, skirt, loin, aitch bone, rump, knuckle, chuck, topside, silverside, brisket, flank, among others (for the aitch bone it was determined that a subsequent device should have more pull force).

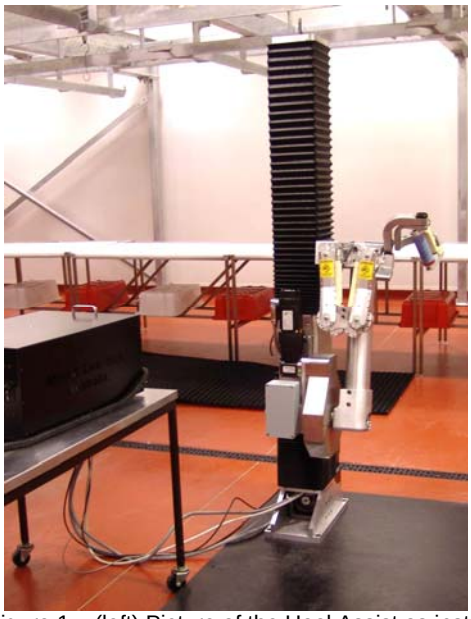

Figure 1 – (left) Picture of the HookAssist as installed at NMIT during the August 2008 Workshop. (right) Boner demonstrating use of the device.

Following the demonstrations round-table meetings were carried out to discuss and capture the audiences thoughts, concerns, comments, and suggestions for a subsequent design. These are included in the following sections.

4 General Requirements for Phase 3

Req 010 - Design gimbal structure so that it does not interfere (collide) with the user's hand/wrist.

Summary: During the demo it became clear that the Hookassist 0.1 gimbals interfered with the user during a pull as the gimbals descended below elbow height. The interference was with the back of the wrist, imparting a torsion in the YZ plane which subsequently increased the downward pressure on the user intent sensor. This created a positive feedback loop during which the device behaved in a non-intuitive manner and a painful pressure on the wrist required the operator to adopt a very non-ergonomic posture in order to continue with the pull.

Workshop Comments:

- One of the joints of the gimbal stands in the way of the wrist and the boner keeps hitting it. Place that joint/axis out of the way
- Sometimes the gimbal seemed to be jammed and could not be brought backwards. As this problem seemed to happen when moving the arm at its lowest position it could be a combination of the system being too low and one of the joints of the gimbal standing in the way of the boner's wrist. Both problems have been highlighted already.

Kinea Design:

- Gimbals impacting the wrist was every ones number one issue. Brian, the boner that used it most, adapted his movements (adopting a poorer bent posture) to avoid this as much as possible but still showed me a red/sore wrist at the end of the day. The operators felt there was a lot of potential in the device in spite of the wrist thing and Brian thought that if the work-height was better adjusted he would choose to use the device even with the wrist issue given the choice. Soon after first using the device I explained to Brian and Corey (the other boner) that a problem with the prototype was that once the gimbals hit the wrist the device could no longer clearly determine what they wanted to do. This explanation relieved most of their confusion with the device pulling down harder than they meant to.

Req 020 - Design the gimbal handle shape to facilitate hook control, meat release, and minimize grip-slip

Summary: The handle of the gimbals would slip in the grip of the operator, reducing their ability to control the positioning of the hook. The handle was round and covered with bicycle grip tape.

Workshop Comments:

- "Need different size handles (for mesh gloves, etc…)"
- "Color coded possibly to match mesh gloves)"
- "Need non slip grip"
- "The grip/handle should be hand shaped so that it does not slide or slip on the hand when applying some force on it."
- The gimbals handle should have an ovoid section. Possibly thermoformed like some existing hooks. Possibly with a knurled / sharkskin type surface.
- "Round handle makes it hard to release the meat after the cut has been made" (and the fact that the handle is in the center of rotation of the gimbal).

Kinea Design:

- Hook handle shape was the second most important issue for just about everyone, certainly all the operators. Here they use moldable thermoplastic handles that have a **oval shape**. They found the existing handle too big in diameter and too slippery (I had fresh bike handle tape on) to control the pitch of the hook. Brian had consistent trouble bringing the device into a working position after acquiring the gimbals handle. He seemed to try to use a thumbless grip on the handle quite often, even after I explained that the thumb needed to wrap around the handle. Corey had no problem.

Req 030 - Device shall tolerate washdown and avoid harboring bacteria, and contaminating product

Summary: The device should not affect the quality of the product. One aspect of this is cleanliness. The device will be washed with high-pressure spray at least daily. The washing is often done by a contracted crew that will not be trained in any of the specifics of the device. The outer casing of the device must satisfy two core requirements: it must protect the inner workings from water damage; it must not have any hidden external surfaces that would be missed in a washdown. Also, the device must not contaminate the product with lubricants or particles.

Workshop Comments:

- "Need to seal and protect from condensate. Plants use 120°C water."

- "Use positive pressure, dip sensors in plastic"
- "75 – 90 °C water for wash down"
- ""accordion" cover has too many nooks and crannies"
- "Have disposable/reusable covers"

Req 040 - Increase the pull force of the device as much as possible without compromising the transparency of the device (the goals is to reach 330 lbf pull force).

Summary: During some cuts operators were able to max out the pull force, and were actually leaning on the device trying to get more 'pull' out of the device.

Workshop Comments:

- John Hughes: Pull force needs to increase to 330 lbf (he measured 578 lbf when pulling a cut straight off)
- More power/grunt
  - "100 lbf is too little"
  - "Boners use their body weight to pull the h-bone"
  - John Hughes: "limit the force based on the type of cut being performed, type of beef (old vs young too)"

Kinea Design:

- Increasing the pull force creates other difficulties in the design so it is important to understand what the minimum useful pull force is. Increasing the pull force requires increasing the size of the structural elements of the machine so that it can pull without danger of structural failure. This increased size means there is more mass to move around, making the creation of a responsive, transparent experience more difficult. Additionally, larger motors are required, which makes safety more challenging.

Req 050 - Device shall be able to be installed either on the floor or ceiling (overhead structure)

Summary: The present approach can be mounted either on the floor or in the ceiling. It is envisioned that the final device will be easily changed for use by left and right handed people.

Workshop Comments:

- John Hughes: "two designs – top mounted and bottom mounted. Lefty/righty capability is down on the list of priorities."
- "Lefty/Righty also needs to be able to address directionality of chain"
- People would not want to dramatically change the boning room to fit the machine
- Mount the system in an overhead rig or gantry
- "Upside down mounting may be preferable, less contamination."

Kinea Design:

- Mounting on ceiling addresses some workspace and washdown issues nicely, however it will most likely require stiffening of the strong back, in order to maintain transparent performance.

Figure 2 - Illustrations of the four different possible configurations that will be possible with the device. From left-to-right the configurations are: floor-right handed, floor-left handed, ceiling[1]-right handed, ceiling-left handed.

Req 060 - Device shall safely address entanglement issues with the chain

Summary: The chain moves under separate control. It's possible that the chain will attempt to pull a carcass further down the line with the hook caught in the carcass or even on the chain itself. The desired failure in this case is for the hook to pull away from the gimbals without damaging the gimbals so that a simple hook replacement is all that is needed to get the line up and running again.

Workshop comment:

- "Need mechanical fuse in case the hook is caught on the chain."
- "Chain never stops in a plant"

Req 070 - Implement safeguards until a Hazards Assessment performed as per the Robotic Industries Association's BSR/T15.1 draft standard for Intelligent Assist Devices – Personnel Safety Requirements reflects a "tolerable"[2] level of risk.

Summary: Industrial robotics have traditionally been regulated such that safety is achieved by keeping people out of the workspace. This device however, is an intelligent assist device therefore we will use as guidance the RIA's BSR/T15.1 draft standard for IADs.

Workshop Comments:

- "Need to clarify the standards under which this equipment falls."
- "What about union acceptance issues?
- John Hughes: no problem with unions – the device helps the worker."

Req 080 - Design the gimbal to return to a "home" orientation when released by operator

Summary: Once the handle is released the gimbal can swing into an awkward orientation making it cumbersome to "untangle" back into the proper 'home' orientation.

Workshop Comments:

[1] Ceiling structure or strong back.
[2] Determining "tolerable" will vary by user or organization, and is a subjective value of acceptance of potential harm.

- Gimbal getting into weird orientations between operations. Hook sticking out into the space of operation.

Kinea Design:

- Both operators at Harvey quickly learned how to grasp the device in the correct orientation regardless of how the gimbals had flopped after letting it go.
- Both operators quickly became comfortable leaving the handle in free-space when they needed both hands for something. The device often drifted a bit; Corey figured out he could place the device at the bottom if the workspace with the Ry arm vertical and it would stay put because of the damping. A virtual spring returning the device to a specific location should be added to the control model.

Req 090 - Implement an electro-mechanical interface that allows for experimenting with different end effectors?

Summary: Alternate uses of the hook-assist device were discussed at the demo. While many ideas were put on the table, the general consensus was to focus on boning operations. Within the context of boning, ideas of alternate ways of manipulating the work were discussed. The most common idea was to try a gripper or pincher end-effector. Should we create a standard interface between the hook-assist arm and the gimbals such that other end effectors can be tested?

Workshop Comments:

- “Gripping functionality. It would be helpful to have the possibility to properly grab a piece of meat, move it and transfer it where it needs to be and release the grip to place it in location (another station where further processing will be performed for instance)”
- “Not only a hook but also a gripper/pincher solution might be helpful”
- “Design and build several interchangeable gimbals with different hook configurations (like different hook shapes, double hook, etc) and a gimbal with gripping functionality”

Kinea Design:

- Even though this interface will be established, it is not expected that this interface will allow for quick-swapping of end-effectors during shift changes, but instead for enabling other configurations of the device.
- Only one end-effector will be developed in Phase 3.

Req 0100 - Reassess the device’s ROM from gathered data

Summary: The workspace of the Hookassist 0.1 device was guided by the study performed by Gary Dennis. During the demo it was observed that there was not enough -Z range of motion available. Some of these observations were during the experimentation with what types of cuts could be made. Some of the observations were made at Harvey beef where the rail was lower than what was expected during design.

Workshop comments:

- One person felt there needed to be more forward and backward workspace available. However, he did not use the device much. The boners regularly ran out of backward workspace but it's my opinion this is because the had run out of vertical workspace (due to the low rail) and were trying to continue pulling long rib cuts.
- John Hughes: “We don't need so much backward workspace.”

    - He had an idea to put a bar across the leg to keep the carcass from coming with the hook.
    - Need to restrict the meat form swinging forward, toward the boner, during a pull. Need a bar that restricts its backward movement. The may dramatically reduce the required ROM.
- Horizontal ROM should be equivalent to the size of a “station”, 5-6 feet
- The main joint is too low, and the boner is forced to lean down to perform some operations. Place the system higher, the boner at a lower level or raise the rail so that the meat hangs higher (this comment was made by the boner trying the system who happens to be a tall guy. All that said it seems the result would be better by implementing this suggestion as similar feedback was heard in the first workshop in Melbourne)
- One person suggested offsetting the gimbals 20cm forward of the rest of the lamp-arm to keep the lamp-arm from hitting product on the rail. I think this is a good thing to investigate.
- “Moving chain situation presents a ROM problem for a fixed device – should travel with the chain”
- “Allow more flexibility and room to move to the boner by placing the robotic arm in front of the tower, while leaving the boner behind the tower.”
- “Put the system on a swivel to cover the work area”
- “Boner had to change his posture because the robot arm was in his way – inverting it will solve this problem”

Req 0110 - Implement a quick-release interface for the Hook such that boners can replace the hook with one of their own design, and/or be able to sterilize the hook easily and quickly if necessary.

Summary: It's common for boners to customize the shape of their hooks. There were several comments about details of the hook shape that affected how well it grabbed meat or let go of meat. The need for hook sterilization and for a mechanical fuse create a natural break in the design that would make this straightforward.

Kinea Design:

- At all points in the conversation with operators they were not worried about the behavior of any specific hook and seemed to assume that just as hooks are now customized in shape by each person, so would the hooks on the hook-assist be customized to the person or the task.
- During the demo at Harvey it was suggested that 30 sec - 1 min for disconnecting, sterilizing, and reconnecting a hook was an acceptable timeframe.

Req 0120 - Design the Hook to have a shorter shank, a more ergonomic form factor, and facilitate meat removal

Summary: Operators had difficulty controlling the hook point accurately. Factors involved are learning to control the device in general, dealing with a 5kg virtual mass with no gravity cues, and the distance from the handle to the hook tip.

Workshop Comments:

- "Hook is too far away, needs to be shorter."
- "Increase the precision of hook insertion."

- “Shorter hook, hook is an extension of a boner’s hand”
- “Current hook is too long, meat gets stuck on it, it is difficult to separate the meat from the hook after the cut is finished”
- “Hook should be both shorter and have less of a “turn around””
- “Boning hook is far away from you hand – that may be responsible for some of the difficulty in fine motor control at the end of the hook”

Req 0130 - Incorporate indicator lights for visually observing the operational state of the device

Summary: It needs to be clear what state of operation the device is in. It needs to be easy to change the state of the device to a safe one. The device will be shut down occasionally during shifts for break periods.

Workshop Comments:

- “Need a way to turn the robot off for break periods. Cork on hook? A place to hang the hook?”
- “Need indicator lights”
- “Green for “in” operation, Red for “not in operation””
- “Emergency stop”

Req 0140 - Incorporate an easily accessible E-Stop switch

Summary: It needs to be easy to change the state of the device to a safe one. The device will be shut down occasionally during shifts for break periods.

Workshop Comments:

- “Need a way to turn the robot off for break periods. Cork on hook? A place to hang the hook?”
- “Emergency stop”

Req 0150 - Implement a mechanical override

Summary: If the device stops working or if the product on the chain is temporarily processed in a different manner, we need to be able to use the area in front of the chain for other tasks. For these reasons we need the ability to fold the device out of the way such that it is in a configuration that is safe to work around.

Req 0160 - Implement sensor data logging

Summary: Ability to log sensor data and faults will be implemented. For the Hookassist_0.2 device, two main categories of information will be collected. 1: Information that will inform Kinea Design in optimizing the production device motors, workspace, and strength to fit actual usage patterns. 2: Information that will allow identifying the causes of failures for rapid diagnostics and preventative maintenance scheduling.

Req 0170 - Eliminate pinch points
Summary: Self descriptive

Req 0180 - Devices input power requirements shall be changed to 3ph, 415 VAC (50 hz)

Summary: Self descriptive

Req 0190 - Focus particular attention on reliability and serviceability

Summary: Actuators with proven track records in industrial applications will be used.

Req 0200 - The hook (with handle) will NOT be detachable as a functional hook

Summary: In the HookAssist 0.1 device a manual hook was designed into the gimbals. The intent was to allow the boner to release the manual hook for separate use. Scenarios included: a desire for faster movement than the machine provided for sub-tasks like marking, removing the hook for sterilization. During the demo it was observed that a second manual hook would be easier to use and that hook sterilization was not as time critical as originally perceived.

Workshop comments:
- John Hughes and others: No need for detachable hook

5 Requirements that will NOT be addressed by Kinea Design

- Chain Tracking
  - System integrator will be responsible for designing and building the chain-following-aspect (with Kinea Design's guidance).
- Device installation and mounting.
  - System integrator will be responsible for designing and building any specific site-integration-structures.

6 Open questions that remain to be answered by MLA or industry experts

- In what timeframe does the left/right handed reconfigurations need to be possible? _____minutes
- In what timeframe does it need to be possible to swap out the hook from the end-effector, for sterilization, purposes, etc…? _____ minutes
- What duty cycle should the device be designed to. How much use during each:
  - Task =
  - Day =
  - Week =
  - Year =
- Verify what was meant by John Hughes' comment that lefty/right configurations are down the list of priorities. Was the intent to say that for this next device we can focus on building a right-handed configuration only device and address lefty/righty at a later time?
- What Australian food safety regulations need to be met?
- Acceptable maintenance schedule?