PorkCAD: Case study of the design of a pork product prototyper

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Abstract: With the help of industry experts we developed porkCAD, an application intended to aid in the communication process between producer and retailer when developing new meat products for a constantly evolving market. The application interface allows the user to make planar cuts to a virtual pig formed from CT-scans of a real-world pig carcass. We present a case study of the design process from conceptualization to intended introduction into the work flow of a meat production company. We discuss critical design decisions during development and present perspectives for future development.

To determine the usability of porkCAD, we tested it with personnel from the pork industry, using two different controller interfaces, one being a traditional mouse and keyboard input, and the other a six degrees of freedom haptic feedback device. The accurate depiction of pig anatomy guided trained professionals to re-create standardized pig products using porkCAD. The quantitative results of the usability test with sales personnel did not lean significantly in favor of either interface. Since one interface was extremely well known and the other highly unfamiliar, the fact that users did not express a clear preference for the known input modality is deemed important. We report on the observed user experience regarding the two interfaces.
Key words: Design Case Study; Graphical User Interface; SUS; Degrees of Freedom; Mouse; Phantom Omni; Haptic Interface; Input devices

1. Introduction

Pig meat is a million dollar industry in Denmark. Approximately 90% of the annually slaughtered Danish pigs are exported all across the world. As a result, the largest portion of the profit derived in the Danish pig meat industry, is the result of product export. The total value of the exported pig meat accounts for almost half the value of the Danish agricultural export. In other words, pig meat is a significant part of Denmark's agricultural profit. Given the heavy stake that pig meat bears in Denmark's economic viability, it is therefore an area of continuing research and optimization. Small improvements translate into huge savings or profits.

In the Danish pig meat industry, the producers own the farms supplying the pigs used in production, which means there is a larger motivation to increase efficiency and/or reduce waste during production, rather than finding cheaper ways of producing the meat itself. Recent efforts include projects such as The Virtual Slaughterhouse (VSH) which demonstrated the viability of applying X-ray computed tomography (CT) and image analysis methods in the context of the abattoir [6,9,17]. This paper presents an alternate approach to further optimizing the meat production process by introducing a virtual product development tool, into the development stage of a new meat product, as visualized in Figure 1, on the left.

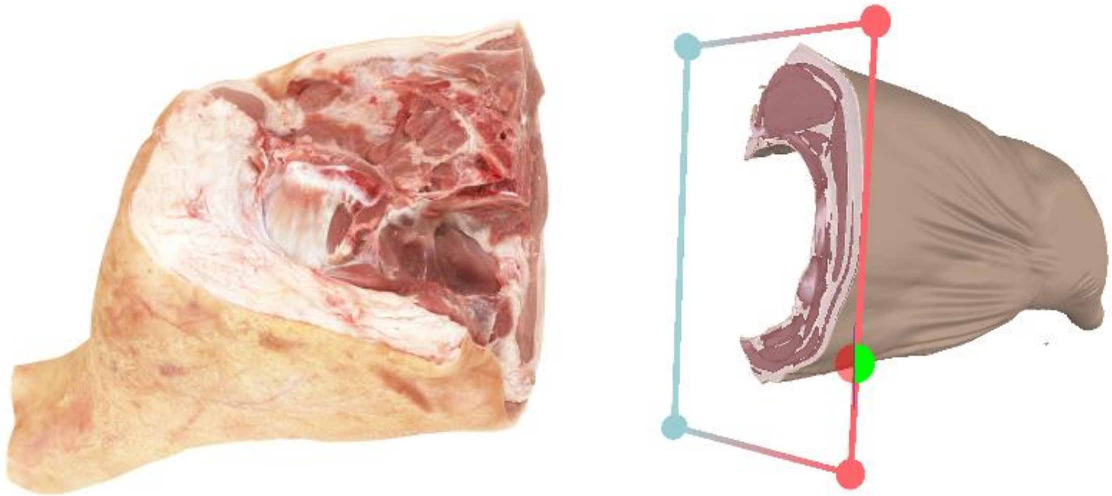

Figure.1 On the left, a standardized meat product: Known as Ham, or 1201 as it's referred to within the industry. On the right, a screenshot from PorkCAD. Showing a direct volume rendered pig carcass with a single cut plane, partially selected via the cursor.

For decades, the development of new fresh pig cuts has involved a long chain of communication, originating from the customer, to the sales personnel, to the company office, to the company production manager, to the cutting operator. The process has traditionally involved a measure of individual decision making at every point in the communication chain. Not surprisingly, the product sample may differ significantly from the customer's original vision of the product in some cases, and thus call for further product iterations. With porkCAD, the chain will be optimized by a sharable visualization tool, ensuring a synchronized vision of the new product by all the stakeholders in the production chain. This harmonized view of a new product reduces the time to market for it, by making the development process more effective, and reducing waste.

This type of virtual prototyping paves the way for many improvements in the future, such as improved product cost projection, which in turn yields a reliable calculation of revenue potential for the producer. The actual cost of a given meat product is determined partially by the complexity of the cutting patterns, as well as which portions of the pig are included in the product. This information allows for better informed decisions at an earlier stage of product development.

We communicated with experts within the Danish meat industry to assess their requirements regarding virtual product development, and designed porkCAD as the first prototype milestone. We present the design process, and evaluation of porkCAD developed in collaboration with the Danish Meat Research Institute (DMRI) [5] and Danish Crown.

PorkCAD renders a virtual pig carcass, based on CT-scanned data from a real pig, and allows the user to create, modify and delete planar cuts. A screenshot from the application is shown in Fig. 1 on the right, showing the CT-scanned pig data cut using a single plane. Planes are created, moved and rotated in real time to fit the users' needs. We designed two separate interfaces: one using a traditional mouse input with the keyboard, while the other uses a six degrees of freedom haptic feedback device. Specifically, the Phantom Omni haptic feedback device © Copyright Sensable Technologies, Inc. [16].

2. Lessons learned

This section briefly sums up critical lessons learned throughout the development, integration and testing of porkCAD, as a service to the reader.

- **KISS Principle** - Despite a simulated butcher knife being an ideal metaphor for the type of interaction we intended to emulate, it overcomplicated the method with which the users were supposed to achieve their goal. Simplicity made porkCAD easier and more intuitive to handle.
- **Analogous behavior** - Using the Phantom Omni provided analogous behavior for rotating and moving objects within porkCAD. The intuitiveness and ease of use this approach afforded the users, compared to the well-known mouse and keyboard interface cannot be overstated.
- **Test planning and resource management** - PorkCAD is to be integrated into an existing workflow populated by personnel who have their own schedules and agendas. Although the end goal is intended to aid them in achieving future goals, the lack of short term return on their time investment in the project means that they must be treated like the precious resource they are. This means that any testing and research that does not absolutely require their participation, be performed in their absence.

3. Related work

This work has its conceptual grounding in computer aided design (CAD) with the end goal of helping the user design a viable meat product, intended for the business market. At the time of writing, we are not aware of any pre-existing publications regarding the modeling of meat products for retail purposes. There is, however, is a significant amount of pre-existing related work. Notably within the areas of computer aided design, volumetric modeling, sketch-based interfaces, and interface usability testing.

Computer aided design, and by extension digital prototyping, has been around for several decades [13]. The food industry already makes use of CAD, but primarily for the purpose of designing the machines handling the food products or designing packaging, not the actual products. This paper presents work covering this previously overlooked area.

In some regards, the design of a meat product is similar to volumetric modeling, for which there exists a large body of research. Perhaps the first paper on this topic was by Galyean and Hughes [7], who present a volumetric sculpting interface using a variety of tools, allowing the user to model a rough replica of an object. The volume is converted into a polygon surface for rendering which degrades the visual quality somewhat. Wang and Kaufman [19] present a more precise sculpting tool in a later article, which is more akin to our work given its similar ray-casting based rendering. Both tools are intended for use with solid material, such as wood and/or marble.

The past decades have also seen significant work being published in sketch based design, as noted by Landay and Myers [12]. A core similarity that sketch based design shares with this work is the intention of improving communication in between people during prototype development. Igarashi et al. [11] present an interface intended for the quick sketch and design of freeform models, such as teddy bears. A key difference from this work is that sketch based design works with much more loose parameters, and in many cases create designs from scratch. Designing meat products require more restrictive methods of interactions and is always based on pre-existing material (such as a pig carcass).

We evaluate the interfaces created in this work by subjecting the target demographic to a formative usability test. Interface evaluation via usability testing is a large area of research, so we will restrict the related work mentioned to papers using similar hardware. Harders et al. [10] perform a study in between multiple 6DOF haptic interfaces where the user is tasked with completing a simple puzzle. Among the devices tested is the Phantom Omni, yet none of them are determined to be significantly superior to any of the others. Plimmer [14] presents experiences with four different pen-dominant software tools, two of which feature a sketch based design environment. She comments on existing usability issues with pen-based forms of interactions, but also notes that users tolerate the inefficiency of the pen in exchange for convenience. Yhu and Lee [21] present the technical aspects of pencil-cut planning and virtual prototyping using a 5DOF haptic haptic interface. Their proposed system is ideal for computer aided design and manufacturing of a near-finalized product composed of rigid materials.

4. Design process

In this section we detail the significant decisions and influences which occurred during the development of porkCAD, beginning with the initial conceptualization, followed by the iterative designs we tested and rounding off with how the final design was tested by the targeted user demographic.

4.1 Conceptualization

One of the biggest challenges facing the Danish pork industry is how to maintain its current high standards of industry safety, product quality, and price, despite the higher expense associated with Danish production costs. There is a strong motivation to cut costs by optimizing product production, rather than reducing costs in obvious areas, such as cheaper labor or cheaper raw materials.

Communicating with a Danish meat producer we found that product production was generally divided into two large categories. New sales, and re-sales. In the latter case, the development cycle is short since the product specifications have been previously agreed upon. In this work we primarily concern ourselves with the former case, which does not involve any pre-existing specifications. A simplified illustration of the basic product development work flow of a new sale is shown in figure 2A.

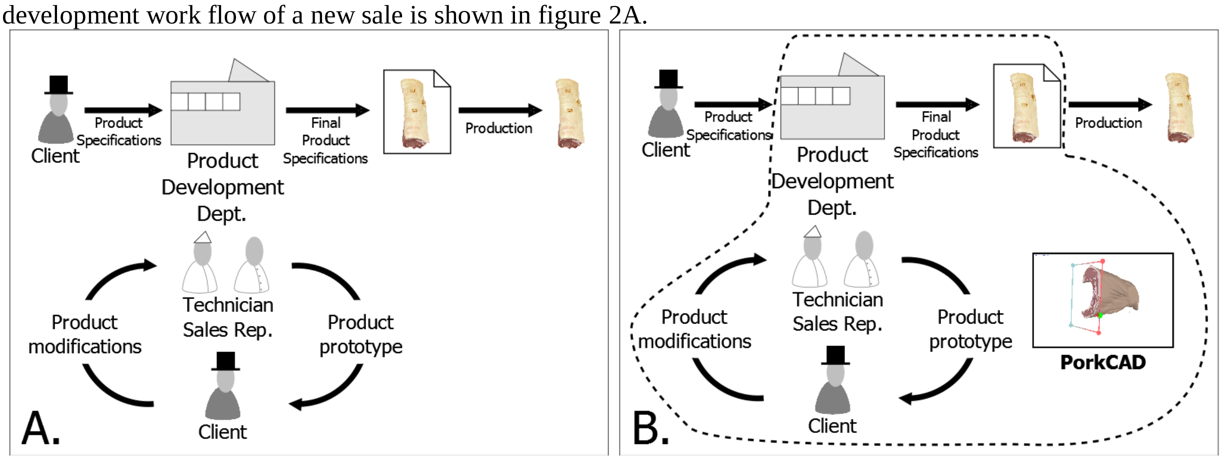

Figure.2A. A simplified illustration of meat product development. Specifications, which are initially provided by the client, are iteratively revised until an agreeable product specification is distilled. These specifications are then passed further along to the production floor which yields the final product. Figure.2B. The workflow pictured in figure 2A, modified with the intended use of porkCAD during product development.

In the beginning, the client provides a set of specifications which are used as a basis in an iterative design process, involving the client, meat technicians, and sales personnel. Given that this communication process is almost exclusively performed in between people, it is rather fluid and non-standardized. The actual discussion will sometimes occur in person, at the meat producer or client's headquarters, and sometimes remotely over one of many existing communication mediums. The involvement of the various parties differs depending on the client and the stage of product development. However, regardless of the development stage and party involvement, the communication is primarily textual, verbal and involves static visuals (pictures). The specific pictures utilized depend on the catalogues available to the client and meat producer. The Danish pork industry makes use of a standardized catalogue dubbed the 'S catalogue', which has evolved continuously since its initial conception decades ago.

After interviewing key personnel involved in the process of negotiating and developing a meat product, it became clear that the tool would serve as a supplement to the current design workflow, rather than replacing any existing portion of it, as visualized in figure 2B. PorkCAD should ideally support the existing lines of communication between the different parties during product development. Although integrating the tool into the actual manufacturing process is an ideal extension of the work - effectively using it for computer aided manufacturing (porkCAM) - we chose to focus on product development first and foremost.

As the workflow diagram shows in figures 2A and 2B, both sales representatives and technicians are involved in the development process. However, the central link in the communication chain is the sales representatives who primarily interact with the client. Technicians serve as advisors during development, rather than a negotiating party.

We determined the following points to be crucial for a successful integration of porkCAD into the existing product workflow:

- **Realistic depiction of pig anatomy** - Pig anatomy can almost be described as a cutting blueprint, which experts use as a guide to produce standardized products, despite biological variations in between pigs. The various muscle groups and bones help the trained butcher in guiding the knife to make cuts according to standardized specifications. A virtual 3D pig carcass is only useful, if the same anatomical landmarks of the pig can be recognized by experts, as on a static photo.
- **Factory reminiscent cuts** - The type of steps involved in cutting a pig carcass to specifications depends entirely on the end product. The type of steps can roughly be divided into two phases. The first phase is fairly automated and performed by heavy machinery, which cuts the pig carcass into more manageable pieces, such as the one visualized in figure 1. The second phase consists of more specialized cuts performed by hand. Products sold in bulk to other distributors usually just pass through the first phase. Retail products sold to individual consumers often pass through the second phase as well.
- **Ease of use** - Although this is practically a preferred requirement for any application, the relative ease of use is quite dependent on the intended target group, and their technical prowess. Since the sales representative is the main link in the chain of communication, we chose this to be our primary target group. The sales personnel have received no formal training specifically related to the prototyping of meat products, and span a wide age gap from the twenties to late fifties (24-58).
- **Mobility** - The pre-existing dynamic process of product negotiation means that porkCAD must be able to run on a portable device. We therefore developed porkCAD to run on an Alienware m17x high-end laptop which, by today’s standards, is easily matched in performance by many other high-end laptops.

We initially drew inspiration from how pork product prototypes are developed without digital prototyping. A set of specifications is iteratively established by the meat producer together with the customer. These specifications are used as a basis for developing a real meat prototype. A real piece of pork is cut by a trained butcher and delivered to the potential customer who provides feedback on the result. The result is either a finished product ready for production, or another iteration of design, beginning with the discussion of new specifications.

A benefit of virtually representing the product prototype is non-destructive prototyping. In essence, we are interested in fusing the various links of the communication chain together and making the process more compact. Committing cuts to a virtual piece of meat while establishing specifications is the result of shortening the communication chain. Of two phases of the aforementioned types of cuts, the most complex are committed by hand. With this as an original inspiration we sought to replicate the actions performed by a real butcher. We looked to a solution that would be able to reliably handle the required actions and is available on the commercial market. The Phantom Omni, pictured in figure 3, was selected as a good initial candidate, able to simulate using a knife to cut a piece of pork as well as providing the necessary six degrees of freedom (6DOF).

Figure.3 Photo of the Phantom Omni haptic feedback device from Sensable, used with permission by Sensable Technologies Inc.

4.2 Iterative porkCAD design

Our initial idea was to allow the user to design a meat product using a simulated butcher's knife. However, this outlook was quickly abandoned since the simulation turned out not to be an effective method for creating a digital meat prototype. The essential tool turned out to be a planar cut. Thus, simulating a knife would lead to a poor division of work between man and machine since the human user would try to make the cut planar (trivial for the machine) while the computer would try to infer the user's intent by fitting a plane to the path of the simulated knife. Despite the sudden lack of use of the haptic feedback abilities provided by the Phantom Omni, the device still turned out to be especially useful for allowing the user to freely rotate and place objects in a virtual scenario.

This simpler form of interaction made the traditional mouse and keyboard setup a viable option. However, the mouse still only provides 2 DOF, which makes performing 3D translation and rotation more complex. We therefore created two separate interfaces, each using one of the following control combinations: mouse and keyboard, and Phantom Omni and keyboard. The primary difference between the two interfaces is how the on-screen cursor is controlled, and how the pig is rotated/moved. Each of the interfaces are described in a later section.

4.3 Testing

We wish to determine if the requirements set forth during the conceptualization of porkCAD are fulfilled. Although the main target group for this application is the sales personnel, they are not the leading authority on realistic cuts and pig anatomy recognition. To ensure that porkCAD faithfully allows real pork products to be prototyped, we approached a factory manager at one of the abattoirs in Denmark, with more than a decade of experience in cutting pork products. With his assistance we created a total of 5 basic products using porkCAD to verify that porkCAD properly depicts pig anatomy and allows for factory reminiscent cuts, and serve as a ground truth with which to compare products created by sales representatives. Prior to involving the sales staff in testing porkCAD, we performed a two rounds of pilot tests which revealed a number of usability issues with porkCAD which were corrected. We recruited 8 sales representatives for a usability test, with whom we tested both of our interfaces. The results of the test is discussed in a later section.

5. Interfaces

Visually, the two interfaces are almost identical. The user is presented with a 3D volumetric rendering of CT-scanned data from a real-world pig carcass. The user has the ability to create, modify, and delete cut planes using the specified controller. Each introduced cut plane is visualized by a solid frame surrounding the pig volume, as illustrated in Fig. 1, on the right.

Apart from the visual representation of the pig carcass depicted in Fig. 1, on the right, the user also has the option to render an x-ray-like perspective of the volume data as visualized in Fig. 4. Using either interface, the **space bar** on the keyboard switches between the two visualization types.

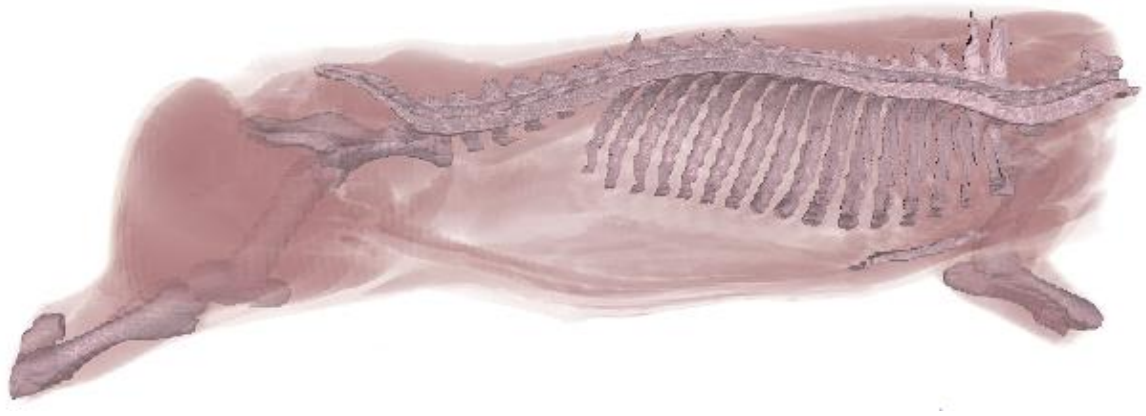

Figure.4 PorkCAD visualizing the volume using an x-ray-like renderer.

5.1 Mouse interface

The left and right mouse buttons are used to manipulate the rotation and XY-position of the pig carcass respectively. Rotation is performed in a fashion similar to the virtual sphere interface described by Chen et al. [4]. The middle mouse button is used to translate the pig carcass along the Z axis.

Pressing **enter** creates a cutting plane, after which the orientation and position can be manipulated in the same manner the pig carcass using the left and right mouse buttons. Visualizations of the various interactions are shown in Fig. 5.

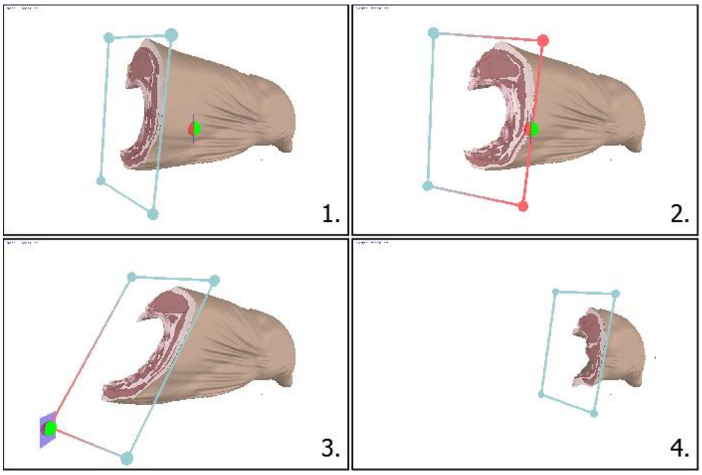

Figure.5 Four different screenshots depicting mouse interaction with porkCAD. 1. A single cut plane applied to the pig carcass. 2. Left mouse button interaction with an edge of the cut plane allows the user to move the two edge end-points around the center of the cut, effectively shifting all four visualized corners. 3. Left mouse button interaction with a corner allows the plane to be rotated along the axis running between the two neighboring points. 4. Right mouse button interaction with any part of the plane allows it to be translated along the pigs' current orientation.

Due to the limited number of degrees of freedom available using the mouse, rotation and translation of the cutting planes, was designed to be restricted around the pig volume. Since the cutting planes remain centered around the pig, the rotation and translation of the cutting planes is slightly different than the rotation and translation of the pig carcass. A cutting plane moves and rotates in relation to the current user perspective of that particular cutting plane. Deleting a cutting plane is accomplished by moving a cutting plane far enough away from the virtual pig carcass.

5.2 Phantom Omni

As illustrated in figure 3, the Phantom Omni has two buttons on the pen. We designate the button located closest to the tip of the Phantom Omni pen, as the forward button, and the other as the back button. The forward and back buttons are used to manipulate the cutting planes and pig carcass, respectively. The 6DOF provided by the Phantom Omni allows for a one to one relation of movement between the controller and a virtual object. Both the pig and the planes move analogously to the Phantom Omni's pen. This relation of movement and orientation between the Phantom Omni and the controlled elements (e.g. pig carcass, planes) follows the principle of least astonishment [15]. The users would expect the elements to move and rotate in the same fashion as they move and rotate the pen on the Phantom Omni. The Phantom Omni also provides haptic feedback when the cursor collides with the pig carcass, effectively allowing the user to rest the cursor on the surface of the pig. The cutting planes have a light magnetic effect to them, attracting the cursor if it is close by.

6. Results

We only had a limited amount of time to make full use of the factory manager and his expert knowledge. We opted to minimize the potential pitfalls during collaboration, by having an expert use porkCAD, guided by the factory manager to perform the cuts he saw fit.

Photographs of the five products alongside the virtual reproductions we created with the help of the factory manager are visualized in Fig. 6. The factory manager could easily recognize pigs' anatomy and place cuts consistent with real world production. The x-ray-like perspective was used mostly for confirmation purposes rather than as an actual guide during product creation. Given that the factory manager is accustomed to cutting the pig in its natural opaque state, this was not particularly surprising.

Figure.6 The five products shown alongside their virtual counter parts. The virtual products shown in the bottom are created using the expert cuts. The most striking visual differences are caused by a lack of physical simulation, most notable in product 1801, where the cut flesh does not even out at the end like in the real world. The other notable difference is skin appearance caused by interpolation most notable in product 1602 and 1801.

The recreation of these five products proved to be feasible by relying exclusively on planar cuts. This is due to the simple design of these basic products, which are often sold wholesale to other distributors.

We calculated a rough measurement of the accuracy of the applied expert cuts, by examining the first three products visualized in Fig. 6. These three products have no overlap, but their collective sum make up the entirety of the pig carcass. Out of the **4261045** voxels comprising the pig carcass, the first three expertly cut products together make up **4262697**, yielding a difference of **1652** voxels, less than 0,1%.

It is reassuring that the sum of the volumes of the expert cuts almost matches the original volume. However, we cannot say for sure whether this is because they are accurate. Fortunately, we can visually ascertain that they are quite accurate, in Fig. 6.

6.1 Usability test

In collaboration with DMRI [5] and Danish Crown we conducted a formative usability study to evaluate potential usability issues as well as ease-of-use of the mouse and Phantom Omni based interfaces in porkCAD. A total of 8 participants, 7 male and 1 female, volunteered from the sales staff at Danish Crown to participate in the test. General information for each participant is listed in table 1, along with their specified interface preference. Each of the participants use computers in their day to day tasks and none of them had had previous interactions with either of the interfaces. Nor had any of the test participants used a Phantom Omni or similar haptic feedback device prior to testing. The study took place at the Danish Crown headquarters in Randers in a meeting room depicted in Fig. 7.

Table 1. The total number of participants in the usability study, along with their age, gender, which interface they were presented with first, and which they expressed a preference for.

Participant	**Age**	**Gender**	**First Use**	**Preference**
1	32	Male	Mouse	Phantom Omni
2	49	Male	Mouse	Phantom Omni
3	53	Male	Phantom Omni	Mouse
4	28	Male	Phantom Omni	Mouse
5	45	Female	Mouse	Mouse
6	37	Male	Mouse	Phantom Omni
7	24	Male	Phantom Omni	Phantom Omni
8	58	Male	Phantom Omni	Phantom Omni

Figure.7 The meeting room housing the test set up for our usability test, complete with complimentary refreshments to motivate participants.

Each of the volunteers were given a short introduction to the system, followed by a five simple tasks intended to familiarize them with the controls. Afterwards the users were asked to recreate each of the five aforementioned products to their own satisfaction. Finally, the users were asked to fill out a SUS questionnaire [3], select a current preferred interface and state the reason for their choice. The whole process took about 60 minutes to complete per volunteer. We asked users to think aloud during the test and express any thoughts they had regarding completing the given tasks.

Out of the three users who selected the mouse as their current preferred interface, two noted that with more time they would prefer to use the Phantom Omni. Calculating the SUS scores collected for each interface according to Brookes [3] and comparing them with the scale established by Brookes et al. [1, 2] rated them both as mediocre (or OK). Apart from a single occasion where porkCAD crashed during testing, all users were able to recreate all of the five pork products. Each product took approximately 1 to 3 minutes to create, approximately correlating with the number of cut planes required to make them.

We noted the following useful observations during the course of the usability study:

- **User fatigue** - A single case of user fatigue was noted during testing with the Phantom Omni interface. While an isolated case, we believe the significance of this should not be overlooked. The Phantom Omni requires a lot of muscle movement by the user, when compared to the mouse, especially involving the wrist. Thus, the age, and by extension the expected health, of the users muscles is of significant important in regards to using the Phantom Omni, in our opinion. Zhai et al. [20] reported a case of user fatigue in their study of muscle groups affecting performance.
- **Plane selection** - On a few occasions, test participants experienced difficulty in selecting a single isolated plane. Specifically, the users had trouble placing the cursor close enough to the plane in order to select it. We considered solutions for each of the interfaces to overcome this issue. In the case of the mouse interface, the thickness of the cutting plane frames could be adjusted to fit the number of nearby planes to allow for easier selection when they are isolated. In the case of the Phantom Omni interface, a direct line in between the cursor and the nearest plane might help mitigate issues with perceived depth.
- **Control confusion** - Users would occasionally mistake the function of one of the buttons with that of another, both in the case of the mouse as well as the Phantom Omni interface. This is likely the result of a too brief introductory phase to porkCAD. Additional visual and audio cues might help users better remember which buttons are assigned which functions as well as longer, more tutorialized, introductions.
- **Phantom Omni continuous button pressing** - During preliminary testing we experienced occasional problems with continuously pressing down the Phantom Omnis buttons. We also noticed similar issues during both pilot tests as well as during the usability study. This is primarily due to the design of the buttons on the Phantom Omni. Ignoring brief periods during which either of the Phantom Omni buttons are released would probably solve the problem.
- **Haptic Feedback** - Haptic feedback has previously been shown to improve accuracy, but not task times, in 3D target acquisitional tasks [18]. None of the test participants seemed to particularly notice the magnetic draw to the cut planes, nor make use of the haptic feedback provided by the pig.
- **Phantom Omni Preference** - Almost all of the users who noted their preference for the Phantom Omni, noted it as being easier to navigate three dimensional space with. A single user noted the preference due to all of the necessary functions being operable from one hand.
- **Mouse Preference** - A single user noted preference for the mouse based on ease of learning and compact size for mobility.

7. Discussion

Our testing has shown PorkCAD to be a usable tool in the context of developing pig product prototypes. The expert butcher was able to recognize relevant pig anatomy in order to recreate five virtual pork products resembling their real world counterparts. The majority of the volunteering sales representatives either preferred the Phantom Omni to the mouse or stated that they would, given more time to practice with the controller.

For the cuts used in the first phase of pork product production, porkCAD fulfills the previously established requirements and can become a valuable tool in the communication process allowing for a less wasteful and more efficient product design cycle, as well as supporting long distance communication without the introduction of additional ambiguity. Although the context of its current usage is limited to communication primarily in between clients and sales representatives, there are numerous ways for expanding upon porkCADs functionality to encompass more elements of pork product production.

- **PorkCAM** - Expanding porkCAD into a full-fledged computer aided manufacturing tool (porkCAM) is an ideal expansion to the existing work. A key step in moving towards a tool intended to aid in manufacturing, is to support the control of the current assembly line robots responsible for automatically cutting the pig carcasses in phase one. This requires a number of constraints to be programmed into porkCAD ensuring that the machinery is operated properly. In order to support manufacturing through phase two, porkCAD would have to be embedded with intimate knowledge of current cutting procedures used by the trained butchers, as well as knowledge regarding the capabilities of the handheld tools used during production. Fogtmann has published work regarding a 'pig-atlas' [8] which would be ideal to integrate into porkCAD to allow cuts to propagate to any conceivable variation of a pig carcass.
- **Deeper workflow integration** - In its current form, porkCAD exports created products and cutting planes for use in a series of other tools which evaluate the product, and generate various statistics such as fat, muscle, bone tissue percentages or approximate production cost. Integrating this functionality or an approximation thereof would further improve the production cycle. This type of knowledge embedding would essentially replicate some of the contributions currently provided by the meat technician. Considerations would have to be made as to how this would affect the production workflow.
- **meatCAD** - An obvious avenue of expansion would be support for alternate types of meat production such as beef, chicken, and lamb. With only slight alterations to the visualization code and a CT-scan of any animal, porkCAD supports planar cutting either animal.

Aside from these conceptual improvements, porkCAD would also benefit from the following technical improvements.

- **Interactive tutorials** - To ease the learning curve using either interface, it would be useful to design and implement a set of interactive tutorials to teach users the controls.
- **Further testing** - We believe that the analogous movements of the Phantom Omni makes it preferable to the traditional mouse. A more exhaustive user test would confirm or deny this hypothesis. This would allow for an exclusive focus on developing the Phantom Omni interface.

8. Conclusion

In this paper we've presented a novel tool for the designing of pork products to be used in the current product workflow of an existing pork distributor. We determined the first complete iteration of the tool to be capable of providing the required visualization and interaction to recreate five basic pork products. PorkCAD works well as a stand-alone tool useful for communication primarily between sales representatives and clients. It is useful for designing new products which pass through the partially automated first phase of pork production. Since most products are further customized in foreign countries where labor is cheaper, this makes PorkCAD an ideal fit for the Danish market. Furthermore, providing support for products created via automation paves the way for developing porkCAD into porkCAM, further reducing the time-to-market for any potential pork product. Our quantitative testing does not significantly favor one interface over another in porkCAD. However, the qualitative testing showed that the volunteers participating in our study either favored the Phantom Omni or stated that they would favor it, given more practice. Interestingly, the force feedback, arguably the Omni's unique selling point, does not appear to be the reason. The main advantage seems to be the analogous interface - i.e. the fact that rotations and translations are so easy and intuitive to specify. Further testing should be performed to verify these claims. We believe that the Phantom Omni potentially offer the best performance given the analogous control of virtual elements it offers. However, a longer introductory period is required to in order to become sufficiently proficient with it.

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