Needs Assessment for Computer-Integrated Surgery Systems

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Abstract. The needs of surgeons for computer-assisted systems cannot be satisfied unless their requirements and expectations are known. We determined surgeons' needs for computer-aided systems using group facilitation processes that measure customer wants and needs, including quality function deployment and Kano Analysis. A one-day workshop hosted by the CISST ERC (Computer Integrated Surgical Systems and Technology Engineering Research Center) included thirteen surgeons and eight engineers. The primary goal of the workshop was to determine medical professionals' needs and expectations at the earliest stages of research and development. Surgeons and nurses from Johns Hopkins Medical Institutions participated in the one-day event. The results include an affinity diagram, a prioritized list of wants and needs in the "voice of the customer", and a Kano Analysis of 25 question pairs that reveal exceptional features that can be included in computer-aided surgical systems.

1 Introduction

Computer-Integrated Surgery (CIS) systems will have a profound effect on 21st Century Medical Practice. A novel partnership between human surgeons and machines, made possible by advances in computing and engineering technology, will overcome many of the limitations of traditional surgery. By extending human surgeons' ability to plan and carry out interventions more accurately and less invasively, CIS will address a vital need to reduce medical costs, improve clinical outcomes, and improve the efficiency of health care delivery.

The development of CIS crucially requires close collaboration between engineering researchers, industry representatives, and clinicians who will use the systems. It is vital that research and system development be directed toward real clinical needs. As is common with emerging fields, there have been a number of "needs and research opportunities" workshops (e.g., [1-4]) directed toward different aspects of computer-integrated surgery. Typically, a mixture of engineering researchers and clinicians attends these workshops. The workshop format usually combines a series of technical presentations with breakout group discussions, followed by a report written by a subset of the participants. The workshop reported here, in contrast, used formal needs and quality assessment techniques to elicit responses from operating room personnel (surgeons, nurses, and technicians). The results provide a useful complement to the reports of the breakout-session workshops.

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2 Background

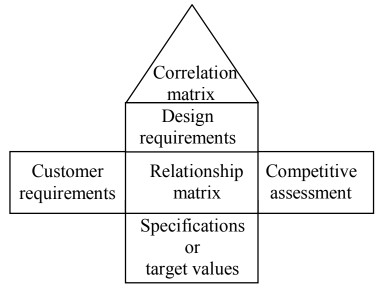

Fig. 1. Termed the “House of Quality” by Hauser and Clausing, this diagram illustrates a relationship matrix for determining users’ needs and translating them into products and services.

Quality is a measure of the ability of a product or service’s features and characteristics to satisfy given needs. The quality of computer-integrated surgery systems is judged by their users, especially surgeons and related medical professionals. We conducted a study to determine surgeons’ needs using formal group facilitation processes, including the construction of an affinity diagram, one component of the “House of Quality” [5]. Kano Analysis [6] was applied to a group of invited surgeons who are interested in computer-aided surgical technologies. The purpose of this paper is to explain the process used to determine surgeons' needs for these technologies and report the results of a one-day planning session where they were applied.

Quality function deployment (QFD), also known as the "House of Quality” and illustrated in Figure 1, refers to the process of involving customers in the design stage of new or redesigned products. [7, 8] The "Voice of the Customer" is the first step of QFD, followed by product development, production, and sales. QFD is a requirements identification, analysis, flow-down, and tracking technique. It focuses on quality and communication to translate customer needs into product-and-process design specifics. In this study, we measured the Voice of the Customer by building an affinity diagram in a group meeting of invited surgeons and related professionals. The affinity diagram is a group decision-making technique designed to sort a large number of ideas, process variables, concepts, and opinions into naturally related groups. [9-11]

Kano Analysis is a method for extracting different types of customer requirements from survey information based on the research and publications of Noriaki Kano, a customer satisfaction researcher and member of the Japanese Union of Scientists and Engineers, sponsors of the Deming Prize. The Kano Model, shown in Figure 2, classifies product attributes and their importance based on how they are perceived by customers and their effect on customer satisfaction. The model measures the level of satisfaction with a product against consumer perceptions of attribute performance. Kano claims that attributes can be classified into three categories [12]:

1. Basic or Expected characteristics provide diminishing returns in terms of customer satisfaction. These are essential or "must" attributes of performance and do not offer any real opportunity for product differentiation. Providing *basic* attributes and meeting customer expectations for them will do little to enhance overall customer satisfaction, but removing or performing poorly on them will hurt customer satisfaction, lead to customer complaints, and possibly result in customer defections. Examples of *basic* characteristics include timely delivery of a magazine subscription, the ever-present telephone dial tone, and availability of an automatic teller machine at a bank branch.

2. Performance or Normal characteristics exhibit a linear relationship between perceptions of attribute performance and customer satisfaction. Strong performance on these "need" attributes enhances, while weak performance reduces, satisfaction with the product or service. Adding more attributes of this type to a product will also raise customer satisfaction. Examples of *performance* characteristics include the duration of a cellular telephone's rechargeable battery life and an automobile's fuel economy.

3. Excitement or Delightful characteristics are unexpected attributes that, when provided, generate disproportionately high levels of customer enthusiasm and satisfaction. When these "nice-to-have" attributes are not available in a product, it does not lead to customer dissatisfaction. Examples of *excitement* characteristics include receiving an upgraded hotel room with free breakfast for the standard rate or finding a CD player included as standard equipment on an economy car.

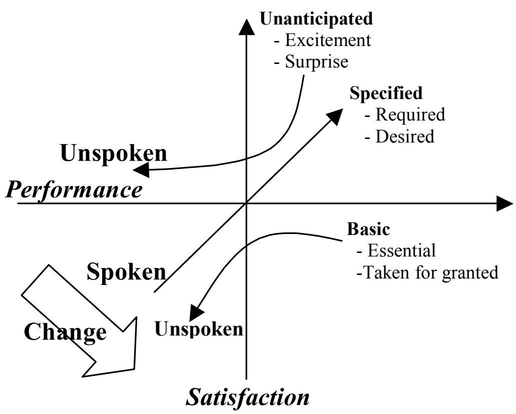

Fig. 2. The Kano Model illustrates the relationship between perceived customer need and product

Both the QFD and Kano processes are means of capturing and analyzing user input regarding the customers' needs and priorities in product development. Such formal needs assessment methods are not new to the medical arena. Both QFD and Kano Analysis have been applied in studies designed to improve patient quality-of-care and customer service in the health care community (e.g.[11, 13, 14]). In our efforts, we aim to cross professional boundaries to better define the needs of operating room personnel with respect to CIS systems and engineering efforts. It is our goal that such a forum will foster more collaboration between CIS engineers and medical professionals at all stages of the research lifecycle.

3 Method & Results

3.1 Method: QFD Analysis

The QFD process [5, 15] is comprised of several steps, each driving towards the goal of having a list of specific, prioritized features to be included in CIS products. The first step in the process is to determine a broad notion of what customers, in our case surgeons and nurses, want from the field of Computer Integrated Surgery. To do this, the customers answer a series of questions. For example, workshop participants answered questions such as, "What do you like about surgical technology as it exists today?" and "If cost were not an issue, what CIS technology or capability would you ask for and why would you want it?" The questions are designed to provoke

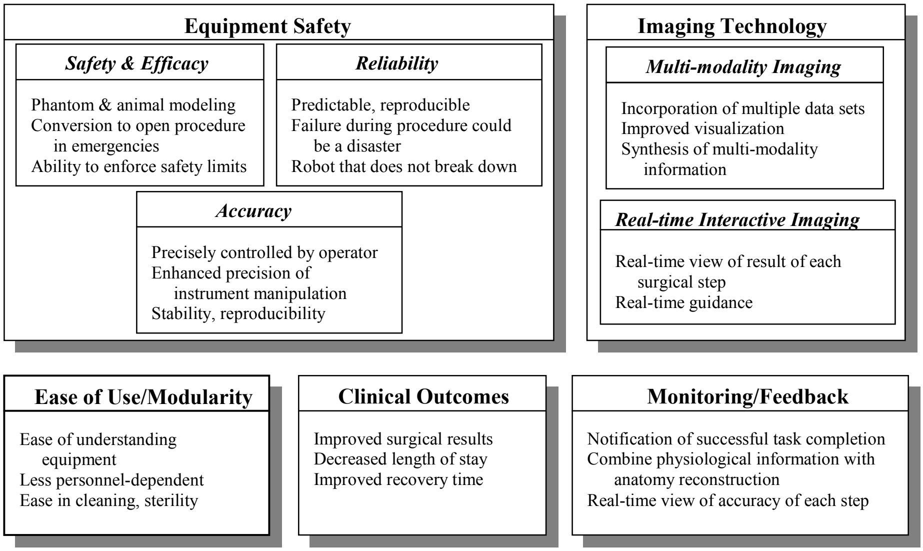

Fig. 3. An Affinity Diagram groups concepts and ideas into a hierarchical list of categories.

brainstorming and to encourage descriptive, freeform responses. Multiple responses to each question are allowed and, in fact, encouraged. Each separate idea is recorded on a separate index card, and all responses are anonymous. At the end of the session, all index cards are collected.

The next step establishes categories into which the users' needs (the responses to questions in the previous step) can be classified. All index cards from the previous step are placed face-up on a table, and the participants are asked to help sort the cards into categories with common attributes. For example, cards stating "no technical support necessary" and "complicated to use" could be grouped together because they both address a system's ease-of-use. Any participant can group, ungroup, or regroup cards as he or she sees fit, and all grouping is done with minimal discussion. Grouping continues until a small, pre-determined number of categories (or card groupings) is established.

After the groupings are established, each group must be given a category name. In this step, it is important to let the users define the name for each category. This allows the users' linguistics to enter the design process from the very beginning. For each stack of index cards grouped together in the previous step, all cards in that stack are read aloud. The participants discuss the group's common characteristics and come to a consensus on what the category name should be. During this process, groupings may be combined or divided as necessary to capture all main ideas presented in the index cards. The category name of each grouping is recorded. In the workshop, a reduced set of ten groupings defined by the sorting process resulted in eighteen unique categories after the naming process was completed.

Finally, a voting process is used to prioritize the categories. Votes vary in value from 1 (feature would be nice but is unessential) to 9 (feature is absolutely essential). Each participant is given a certain number of votes of each value to distribute among

Category	Score
Tier 1	
Safety and Efficacy	**99**
Ease of Use / Modularity	**75**
Accuracy	**66**
Reliability	**65**
Tier 2	
Clinical Outcomes	**49**
Real-time Interactive Imaging	**47**
Monitoring / Feedback / Physiological Processes	**38**
Multi-modality Imaging	**35**
Tier 3	
Training and Logistical Support	**33**
Versatility	**32**
Efficiency	**31**
Extend Human Motor & Sensory Input or Skills	**30**
Tier 4	
Acceptability	**25**
Preoperative Planning and Procedure Practice	**24**
Physical Properties	**21**
Minimal Invasiveness	**19**
Tele-operation / Remote Operations	**12**
Cost	**11**

Fig. 4. The QFD Voting process yields a list of prioritized customer needs.

the categories. The votes are tallied, and the categories are ranked from highest to lowest priority according to points received. [5, 15]

3.1.1 Results: Affinity Diagram & QFD Voting

The results of the QFD Analysis are presented in two forms. First, the affinity diagram in Figure 3 shows the grouping of customer needs into categories. The requirements listed in each category are taken from the index cards completed by workshop participants during the QFD process. A subset (8 of 18) of the categories is shown. Categories sharing common themes can be grouped under common headings, such as reliability and accuracy share the underlying theme of "Equipment Safety". The subset of categories in this figure reflects the top two tiers of results obtained in the QFD voting process. These results are shown in Figure 4. The categories were prioritized based on total score received in the ranking procedure. The actual category names were determined by workshop participants and are listed in the left-hand column, and the right-hand column reflects the total score the category received.

To get a better understanding of what the surgeons' and nurses' ideas mean, the discussion about the results was open to both the workshop participants and CIS engineers who did not participate in the QFD process. The discussion proved to be lively and enlightening. A good deal of discussion focused on the top tier of results. We were surprised to find that these four features are not CIS-specific but, instead, can apply to any consumer product. From the engineers' perspective, clinical customers should assume these features, just like you assume a telephone will have a dial tone. However, our workshop participants decidedly ranked these categories at the top of their list of needs. This further illustrates the need for greater customer input during the development of CIS products. With greater communication and involvement, perhaps the medical community would come to view these 'Tier 1' features as guaranteed. The customers of our survey, however, apparently do not believe that such a guarantee currently exists.

Moving to the next tier of results, features that are more CIS-specific are found. Clinical outcomes, real-time interactive imaging, and monitoring address specific needs which surgeons deem to be of high priority in any CIS application. It is here that research initiatives can begin to find motivation from the medical arena. Knowing that medical professionals deem these features to be of high importance in CIS systems, future research initiatives can focus more directly on these areas.

We were surprised to find "hot topics" such as minimal invasiveness, remote operation, and telemedicine at the bottom of the priorities list. Surgeons explained that the definition of minimally invasive differs from procedure to procedure, and each procedure must strike a balance between being minimally invasive and giving the surgeon adequate control in the operating field. With respect to telemedicine, workshop participants were simply not focused on this as a need.

Responses to the Negative Question

Responses to the Positive Question	**Kano Analysis**		A	B	C	D
			Like	Normal	Don't Care	Don't Like
	A	Like		Delightful (A,B)	Delightful (A,C)	Normal (A,D)
	B	Normal				Expected (B,D)
	C	Don't Care				Expected (C,D)
	D	Don't Like				

Fig. 5. The combination of responses to the positive and negative Kano questions determine which category a given feature falls into: *Expected, Normal, and Delightful.*

3.2 Method: Kano Analysis

Kano Analysis was used in the workshop to better understand the unspoken requirements from users. This method helps discriminate between what users say (e.g., Voice of the Customer) and what they think. [6, 9, 11, 12] This method focuses on the end-users' expectations of a product and its features. Participants are asked a series of positive and negative question pairs, 25 sets in all. Each positive question is stated in the form, "How do you feel if our product has X?" while the corresponding negative question asks, "How do you feel if our product does not have X?" Participants choose from four possible responses: (a)I like it, (b)It is normally that way, (c)I don't care, or (d)I don't like it. In our case, workshop participants answered positive/negative question pairs such as: "How do you feel if our product includes a robot?" versus "How do you feel if our product does not include a robot?" and "How do you feel if our product provides a single monitor with 2D fluoroscopy?" versus "How do you feel if our product does not provides a single monitor with 2D fluoroscopy?".

Analysis of the results considers the voters' response to both the positive and negative phrasing of the same question and categorizes the combined responses as *Delightful*, *Normal*, or *Expected*. [9, 10] Relating these responses to the attribute characteristic explained previously, a *Basic* characteristic can elicit an *Expected* response, a *Performance* characteristic can elicit a *Normal* response, and an *Excitement* characteristic can elicit a *Delightful* response. The correlation grid for Kano Analysis is shown in Figure 5. The grid defines response pairs associated with each category. For example, a "Like" response to the positive question combined with a "Normal" response to the corresponding negative question results in an (A,B) voting pair and is categorized as a "Delightful" response. Notice that many response combinations do not reflect any conclusive result and therefore cannot be categorized.

3.2.1 Results: Kano Analysis

A sample of the Kano Analysis results from the Needs and Priorities Workshop can be seen in Figure 6. A subset (14 of 25) of the features addressed is included.

Expected	Single Monitor with 2D Fluoroscopy
Normal	Automatically Move Scalpel/Needle Force Feedback Control Monitor the Therapy in Progress Operates Without Imaging Delays Submillimeter Resolution
Delightful	Instrument-tip Imaging Direct link to Imaging Scanner Voice Control Tremor-free Motion Control Intraoperative Ultrasound Imaging Uses 3D Imaging Superimposes 3D Anatomy Teleoperation Capability

Fig. 6. A sample of the results obtained from the Kano analysis process reveals a lack of established, i.e. expected, features in CIS applications.

Column headings reflect which of the characterizations the feature received in the analysis process.

Perhaps most interesting is the fact that only one feature was decidedly categorized as "expected" in CIS technology. The surgeons and nurses who participated in the workshop assume that modern CIS products do include or use a "single monitor with 2D fluoroscopy". Several features were categorized as "normal", including force-feedback control and submillimeter resolution. Of the 25 features included in the analysis, an overwhelming majority of seventeen features were decidedly categorized as "delightful". These features, including voice control and 3D imaging, are not viewed as common parts of current CIS technology. Through these results and the discussion that followed, workshop participants confirmed their openness to CIS technology. However, participants also expressed concern that CIS has not defined and proven itself by establishing a large number of features that are viewed as "expected" in CIS products.

4 Discussion

We consider the results we obtained from the QFD and Kano techniques to be provocative while acknowledging that no single study can be conclusive. In our case, the results provide useful insight into the mind of the customer. However, a greater depth of analysis would be useful for future workshops. Several improvements could lead to more comprehensive results. One way in which improvements could be made is gathering more information about workshop participants. Specifically, it would be useful to survey participants on their current level of technology use and overall receptiveness of technology in the workplace. Results could then be interpreted with an understanding of the participants' feelings about technology. Additional improvements might be achieved by subgroup analysis. Grouping results into subgroups such as doctors, nurses, and technicians would likely reveal interesting and useful results that do not arise when the groups are analyzed as one. The difficulty in this case lies in gathering such a varied and well-balanced group of individuals from the medical profession for participation in a day-long workshop. When applying these analysis techniques, careful planning will afford the desired level of detail.

The results of both analysis techniques lead to candid discussion between the medical professionals who participated in the process and the engineers who design CIS systems. One key point that arose was a language difference between medical and engineering professionals. Key terms used during the workshop and, more importantly, in professional collaborations between the groups, carried different meanings for the two communities. For example, the engineering and medical communities represented at the workshop carried different understandings for the meaning of the term “modularity”. Both groups shared the basic definition of modularity as “plug-and-play”, i.e. pieces of a modular device are interchangeable. However, medical professionals extended this meaning to encompass fault-tolerance and fault-recovery capabilities. The individual units of a modular device, claimed the surgeons, should continue to operate in a safe and consistent way even if other units in the same device fail. In addition, surgeons expect modular devices to include on-the-fly recovery mechanisms. For future analysis sessions and collaborations, a common and consistent vocabulary of CIS-related terms is essential for clear communication between surgeons and engineers.

Another point of interest was the surgeons’ perception of the CIS field. Medical professionals and CIS engineers, it seems, have different approaches to the design of clinical applications. The surgeons tended to focus on *existing* surgical techniques and look for ways to improve them in order to produce better clinical outcomes reduced less cost and labor. The surgeons perceived engineers as frequently focusing on *non-existing* applications, overlooking less complex, intermediate solutions that could be very effective. For example, one surgeon presented the seemingly simple task of moving a patient during surgery. A given patient must be moved multiple times during surgery and, each time, a team of medical personnel must lift the person by hand. Something as simple as a way to move patients around in the operating room, it was suggested, would be very beneficial.

5 Conclusions

A common theme in all discussions was that CIS must strike a balance between being visionary and meeting the current needs of its customers. In seeking this balance, both the QFD Voting and Kano Analysis methods proved useful for the goal of defining research initiatives and direction. By utilizing these processes, it was guaranteed that both the engineering and the medical community’s needs would be fully addressed. The QFD Voting process forced the participants to work together to define and name categories of importance from a medical point-of-view, ensuring that the focus of the analysis was correctly targeted to the end-users. The Kano questions, on the other hand, were pre-determined by CIS engineers and therefore approached the issue from an engineering point-of-view.

Within the CISST ERC, the results of the Needs and Priorities Workshop have provided insight into how best to allocate its research resources to meet its customers’ needs. The results also reveal the greatest challenge for CISST ERC research: current CIS technology has yet to be fully embraced by

Workshop Participant	Specialty
Randy Brown, DVM, MSc	Comparative Medicine
Gaylord Clark, M.D.	Orthopedics, Hand
Theodore DeWeese, M.D.	Radiation Oncology, Urology
Frank Frassica, M.D.	Orthopedics, Bone Cancer
Tushar Goradia, M.D., Ph.D.	Neurosurgery
Brian Kuszyk, M.D.	Radiology
Byron Ladd, M.D.	Ophthalmology
Nadine Levick, M.D.	Pediatrics
Lee Riley III, M.D.	Orthopedics, Spine
Daniel Rothbaum, M.D.	Orthopedics
JoAnne Walz, D.S.N.	Neurosurgery
Keith Wiley, A.A., B.A, B.A.	Neurosurgery
David Yousem, M.D.	Neuroradiology

Fig. 7. The surgeons and nurses who participated come from a variety of specializations and represent a wide scope of customer needs.

the medical community. It is the goal of those involved that the workshop proceedings permanently open doors of communication between surgeons and engineers that will prove invaluable in future collaborations and help establish CIS as a trusted partner in medical solutions.

Acknowledgements

The surgeons and nurses from the Johns Hopkins Medical Institutions who participated in the Needs and Priorities Workshop are listed in Figure 7. We appreciate their willingness to provide their opinions and expectations that serve as the basis for the needs assessment reported in this paper.

References

[1] R. H. Taylor, G. B. Bekey, and J. Funda, "Proceedings of the NSF Workshop on Computer Assisted Surgery,", Washington, D.C., 1993.
[2] A. DiGioia and et al., presented at NSF Workshop on Medical Robotics and Computer-Assisted Medical Interventions (RCAMI), Shadyside Hospital, Pittsburgh, Pa.: Bristol, England, 1996.
[3] D. Winfield, "Final Report of the Working Group on Image Guided Therapy," USPHS Office of Women's Health and National Cancer Institute, Research Triangle Institute, Research Triangle Park April 12-14, 1999 1999.
[4] K. Cleary, "Workshop Report: Technical Requirements for Image-Guided Spine Procedures," Georgetown University Medical Center, Washington, D.C. 113, April 17-20, 1999 1999.
[5] J. B. Revelle, J. W. Moran, and C. Cox, *The QFD Handbook*: John Wiley & Sons, 1998.
[6] N. Kano, "A Perspective on Quality Activities in American Firms," *California Management Review*, pp. 12-31, 1993.
[7] Y. Akao and S. Mizuno, *QFD: The Customer-Driven Approach to Quality Planning and Deployment*. Asian Productivity Organization: Productivity Inc., 1994.
[8] Y. Akao, *Quality Function Deployment: Integrating Customer Requirements into Product Design*: Productivity Press, 1993.
[9] G. A. Churchill and C. Suprenant, "An investigation into the determinants of customer satisfaction," *Journal of Marketing Research*, vol. 19, pp. 491-504, 1982.
[10] H. K. Hunt, "Conceptualization and measurement of consumer satisfaction and dissatisfaction,". Cambridge, MA: Marketing Science Institute, 1977.
[11] B. King, "Techniques for understanding the consumer," *Quality Management in Health Care*, vol. 2, pp. 61-67, 1994.
[12] R. Jacobs, "Evaluating Satisfaction with Media Products and Services: An Attribute Based Approach," *European Media Management Review*, 1999.
[13] E. Chaplin, M. Bailey, R. Crosby, D. Gorman, X. Holland, C. Hippe, T. Hoff, D. Nawrocki, S. Pichette, and N. Thota, "Using quality function deployment to capture the voice of the customer and translate it into the voice of the provider," *Joint Commission Journal on Quality Improvement*, vol. 25, pp. 300-315, 1999.
[14] E. M. Einspruch, V. K. Omachonu, and N. G. Einspruch, "Quality function deployment: application to rehabilitation services," *International Journal of Health Care Quality Assurance*, vol. 9, pp. 42-47, 1996.
[15] L. Cohen and L. Cohen, *Quality Function Deployment: How to Make QFD Work for You (Engineering Process Improvement)*: Addison-Wesley Publishing Co., 1995.