AC 2010-511: COMMUNICATION NEEDS IN COLLABORATIVE AUTOMATED SYSTEM DESIGN

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Communication Needs in Collaborative Automated System Design

Abstract

Design of automated manufacturing systems is a highly collaborative endeavor, requiring constant communication between a customer (typically a manufacturer), a team of system integration engineers, and suppliers. There are three layers of activities involved in designing an automated manufacturing system. First, the engineers need to capture what the customer wants. Second, the engineers need to know about the various mechanical and electrical devices that make up the system and the control programs needed to orchestrate and synchronize the process being automated. Third, the engineers need to identify vendors and equipment for the system.

Web-based instructional materials and problem-solving environments are being built to help engineering students and new engineers to acquire the subject knowledge and skills needed to contribute to these activities. However, the focus of these tools thus far has been on educating individual learners. Needed are instructional tools that can allow engineering students to collaborate with other students and industry engineers to solve realistic problems in a realistic way, and thereby better prepare them for industry jobs. The recent surge in use of Web 2.0 tools (such as social networking, blogs, wikis, web conferencing, and shared applications) suggests that these technologies are now mature and well-established enough to become a regular part of engineering education.

This paper describes developments in an ongoing NSF project that aims to combine instructional materials for system integration problem-solving with Web 2.0 tools to create collaborative learning environments that allow teams to work and learn together in solving system integration problems. The first stage in this project involves the following steps: 1) identify what modes of communication are currently being used to facilitate collaboration within the system integration industry; 2) determine how this communication culture be translated into a virtual collaborative problem-solving environment; and 3) summarize constraints, needs, goals, and factors affecting the success of system deployment. Results from this stage will be used in identifying and designing the tools that should be made available in a collaborative environment for learning automated system design.

Background

System integration refers to all the tasks related to designing, building, testing and fielding an automated manufacturing system. An automated manufacturing system generally consists of processing equipment, material handling devices, and material transfer equipment. The processing equipment can be a computer numerical control (CNC) milling, lathe, turning machine or any other type of equipment that changes or alters a property of the work piece. Material handling devices include industrial robots, actuators, and others devices that handle the work-in-process work-piece at the workstations. Material transfer equipment, such as conveyors, is often used to move raw materials from bins to a destination where they can be picked up by material handling devices. A system controller, such as a programmable logic controller (PLC), works behind the scenes to orchestrate and synchronize the operations performed by the equipment. Figure 1 shows a sketch of a robotic assembly cell, which is one type of automated manufacturing system.

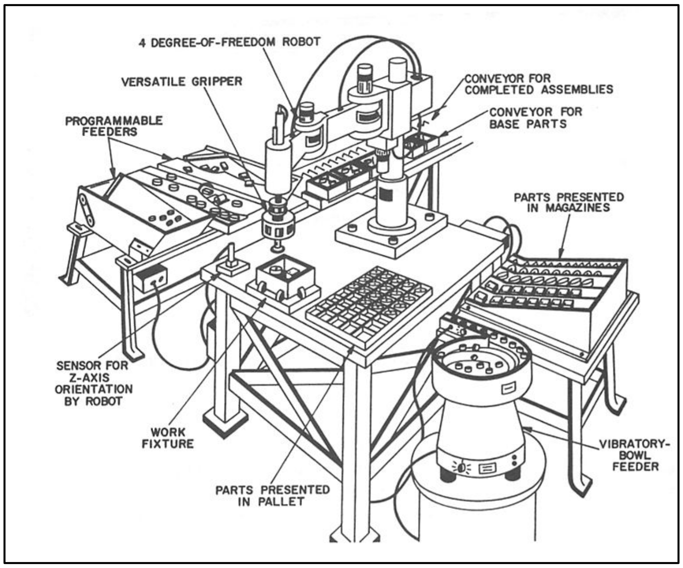

Figure 1. Example of robotic assembly cell (from Rampersad, 1994).

Automated manufacturing systems are typically built by teams of engineers (Hsieh, 2005). A project typically starts with a sales contact that indicates a customer has a need. An applications engineer works with sales and the customer to develop a proposal, which includes a description of customer requirements, a conceptual design to satisfy the needs, and a contractual agreement, which includes a budget and schedule. The conceptual design will identify the sequence of operations and corresponding devices. Also, the cycle time of the line will be estimated and/or simulated using a computer model or static diagram. Once the proposal has been accepted by the customer, a control engineer and a mechanical engineer will work side by side to design, integrate and test the system. The control engineer handles the control logic design and integration of associated devices such as PLC, sensors, and robots. The mechanical engineer works on tasks associated with mechanical components, such as gripper design, fixture design, and motor motion devices.

The boundaries between roles are not clear-cut and often vary from project to project. For small projects, one person may handle multiple roles. Larger projects will require more personnel and include additional roles, such as software engineer and electrical engineer. The constant influx of new projects and the time-sensitive nature of the business make it necessary for engineers to work closely together, to learn about each other's jobs, and to share ideas and experiences. Engineers also work closely with their customers, to better meet their needs, and with equipment vendors, who help the system integrators to identify potential system components and provide support for integrating the equipment within a system. When asked what skills new engineers need in order to be successful in the system integration industry, engineers consistently identify team work and the ability to communicate as essential skills (Hsieh, 2005).

Often the key players on a project are in different locations. For example, a system integration firm in the Southeastern U.S. could have a contract with a manufacturer on the West coast to build an assembly line that will ultimately be used in Southeast Asia. In building the system, the system integration firm may need to purchase equipment from multiple suppliers located throughout the U.S. and the world. So collaborating over a distance is essential to the business. With the rise of Web 2.0 tools, we expect to see increased use of web conferencing, shared applications and other web-based collaboration tools in the future. To facilitate the development of appropriate collaboration tools, it is important to understand which tools are being used today and how, current deficiencies, and desired improvements. In addition, it is helpful to understand if different tools are used or required for different types of system integration activities and different market segments.

To address these questions, the author is in the process of conducting a survey of engineers at system integration firms across the U.S. The survey distribution began in mid-December, 2009 and continued through spring of 2010. This paper reports preliminary findings.

Methodology

An online survey was created and distributed to engineers at system integration firms across the U.S. The engineers invited to participate either worked for companies that the author had previously contacted or visited or were members of a national association for system integrators. Data collection began in mid-December, 2009, and approximately 200 engineers were invited to participate. As of January 2010, 18 had completed surveys, for a response rate of 10%. The surveys were anonymous.

Respondents were asked to provide basic demographic data such as job function, job level and the market segments they worked in. They were then asked to indicate whether or not they were involved in design of new automated systems, maintenance/retrofitting of existing automated systems, and/or troubleshooting of existing automated systems. For each of type of activity that they were involved in, they were then asked about the types of communication tools they used and how, current deficiencies, and desired improvements. As an example, below is the survey section on design of new automated systems:

4. Does your job involve working with customers to design automated systems? (yes/no)

If your answer to question 4 above was No, please skip to question 9.

5. Please enter the percentage of time that you use each of the communication methods listed below when helping customers to design a system. The total should add up to 100%.

Telephone	
Fax	
E-mail	
Instant messaging	
Web conferencing	
Face-to-face meetings	

6. Please briefly describe how each of these methods of communication helps you in communicating or coming up with a design.

Telephone	
Fax	
E-mail	
Instant messaging	
Web conferencing	
Face-to-face meetings	
Other	

7. What are the deficiencies, if any, in using the above methods of communication for design?

8. What improvements, if any, do you wish you had for communicating about system design?

Results

Job function and job level

Respondents' job functions and job levels are indicated in Figures 1 and 2, respectively.

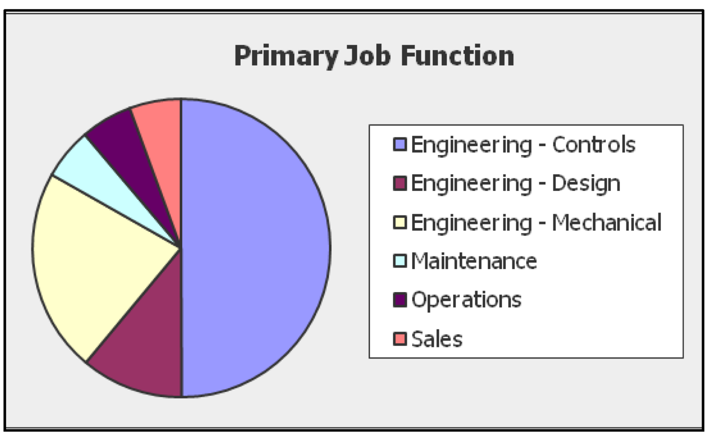

Figure 1. Primary job functions of survey respondents.

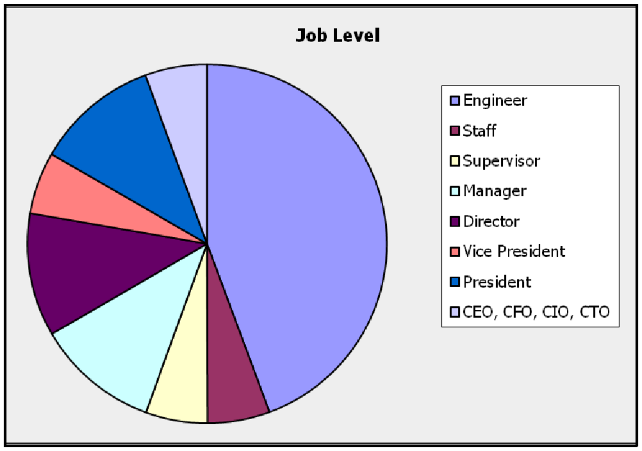

Figure 2. Job levels of respondents.

Market segments represented

Respondents were asked to indicate their primary market segment. If they indicated more than one market segment, they were asked to indicate the percent of time spent in each segment or industry. The response totals was required to sum to 100%. Table 1 shows the market segments represented.

Table 1. Market segments represented by survey respondents.

Market Segment	No. of Respondents	Average % Time Spent
Automotive	8	36.25
Machine builder (OEM)	7	46.43
Medical device assembly and test	7	52.86
Food & beverage	6	30.00
Water/wastewater	6	24.17
Energy storage and distribution	5	12.00
Household, personal care & chemical	5	11.00
Life sciences	4	17.50
Metals	4	17.50
Materials handling & logistics	3	6.67
Oil & gas	3	16.67
Packaging	3	11.67
Semiconductor & electronics	3	16.67
Fibers & textiles	2	7.50
Mining, aggregate & cement	2	20.00
Tire & rubber	2	12.50

Most frequently used communications methods

Participants were asked to indicate the percentage of time they used each of six methods of communication (telephone, fax, e-mail, instant messaging, web conferencing, and face-to-face meetings). Each participant's total percentage across all six methods was required to add to

100%. Figures 3-5 depict the average percentage of time that respondents used each of the communication methods in each of the three types of system integration activities (design of new automated systems, maintenance/retrofitting of existing automated systems, and troubleshooting of existing automated systems).

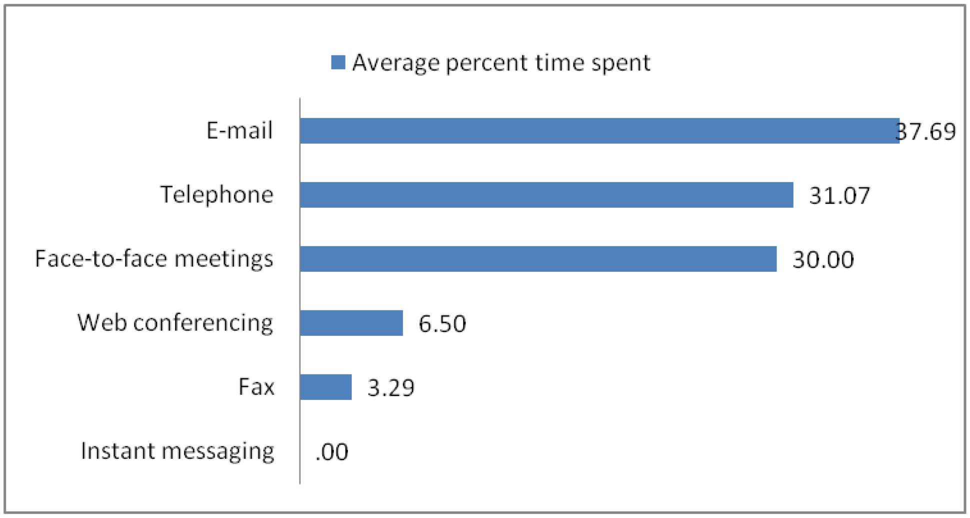

Figure 3. Communication methods used in designing new automated systems.

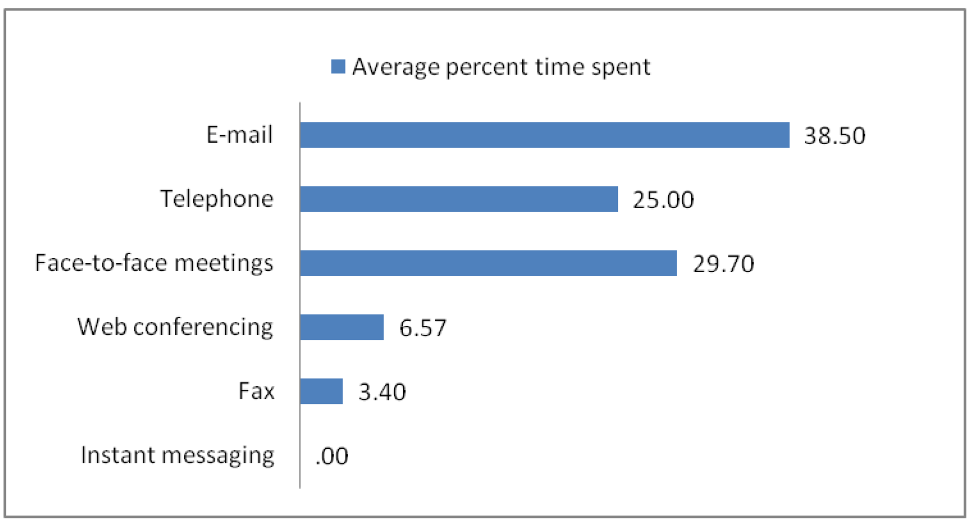

Figure 4. Communication methods used in maintaining, upgrading, or retrofitting existing automated systems

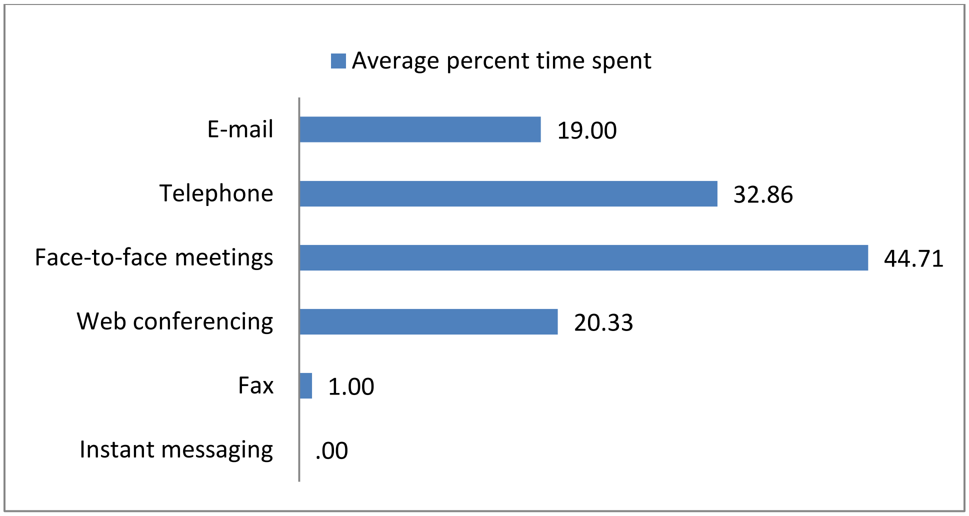

Figure 5. Communication methods used in troubleshooting existing automated systems.

The data suggest that e-mail, telephone, and face-to-face meetings are by far the more commonly used method of communication for all three types of activities. For design and maintenance-related activities, e-mail is the most commonly used form of communication, followed by telephone and face-to-face meetings. For troubleshooting, however, telephone and face-to-face meetings are used the most, and e-mail is in third place.

After the top three, web conferencing is consistently the fourth most used method of communication. Based on the comments in other sections, however, it appears that web conferencing is viewed positively and its usage may eventually expand. Instant messaging and fax appear to have very limited usage.

<u>Uses and perceived deficiencies of various communication methods</u>

For each of the three types of system integration activities, participants were asked to describe how each of the six methods of communication—plus any others they used—was helpful. They were also asked to identify deficiencies with these methods of communication. We found that for the most part there were no differences in participants' responses to these questions across the three types of system integration activities, so the responses were merged. Table 2 shows the combined responses.

Table 2. Perceived benefits and deficiencies of various communication methods.

Communication method	**Helpful for…**	**Deficiencies**
Telephone	Quick answers to questions	Both parties need to be available. Documentation of conversations is not automatic. Can't see the customer or the equipment. Communication is difficult if there are language differences (foreign customers).
Fax	Hard copy for records; transmitting information in non-traditional file formats; back-up when Internet is unavailable	Not real-time; superseded by newer technologies.
E-mail	Keep team informed; provide record/documentation of requirements and discussions; ask questions; nail down facts	Can't see the customer. E-mails can be ignored or not read. E-mails can be misunderstood.
Instant messaging	No responses provided	Perceived as "not for grownups."
Web conferencing	Save on travel costs; quick communication; show models or explain concepts.	All users need to have the necessary equipment available; audio quality sometimes poor.
Face-to-face meetings	"Reading" the customer; brainstorming; see body language; relationship-building; good for reviewing large amounts of information. In troubleshooting, allows ready access to system.	Travel is time-consuming and costly. Need to bring papers, files, and samples. Documentation is not automatic.
Other: FTP	Sharing of project documentation	No responses provided
Other: VMware/remote login	See displays remotely	Security risks because system is exposed to external access.

Desired improvements

Participants were asked to identify desired improvements in communications tools for each of the three types of system integration activities. The responses were summarized and listed below.

- Better e-tools for virtual meetings, acceptance testing, etc. to minimize travel.
- Communications should be self-documenting and become part of the project record.
- Better compatibility between CAD files.
- An easy web-based conference software package that would allow easy document sharing.
- Better audio for phone communication and web conferencing.

- For troubleshooting, better remote access programs for PLC/HMI and better support with remote login to view but not control.

Discussion

Clearly, for all three major types of system integration activities, the “big three” methods of communication are e-mail, phone, and face-to-face. Troubleshooting seems to have slightly different communication needs than design or maintenance/upgrade/retrofitting, however. With troubleshooting, clear and rapid communication and access to the system (either on-site or remotely) seem to be especially critical. Currently, face-to-face meetings are most used for troubleshooting, but due to travel costs and time, there is a strong desire for better remote access and communication tools.

Web conferencing tools were not in the big three, but were a consistent fourth option. Respondents seemed generally open to using them. The primary obstacles seem to be having the necessary equipment available and technical issues, such as audio quality. Fax appears to have been superseded by e-mail and instant messaging seems to be a non-starter, perhaps because it is not perceived as a tool for workplace use (or at least for use with customers).

Based on the participants’ responses, we can make some inferences about communication needs in the system integration industry. These include:

- Need quick answers to questions (e.g., to get better understanding of requirements).
- Make sure everyone has same understanding.
- Need documentation of discussions (preferably easy/self-documenting; should not require taking notes).
- Secure remote access to systems when troubleshooting.
- Need to be able to “read” the customer (interpret body language).
- Need to be able to show things.
- File compatibility (e.g. CAD files) an issue.

Future Directions

Findings from this survey will inform future design of a collaborative learning environment (CLE) for automated system integration. The CLE will need to provide tools to support typical communication needs within the system integration industry. These tools may not be the same as current tools, but they need to provide the same affordances, so that learners and other participants in the CLE will be able to have realistic communication exchanges (http://en.wikipedia.org/wiki/Affordance provides more information about the concept of affordances). Possible technologies include improved web conferencing, improved tools for remotely and securely accessing automating systems, smart tablets, smart phones, and standard file formats for exchanging technical data, such as CAD drawings.

Acknowledgements

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