

Embedded HMI Design and Development

Learnings from a Decade of Experience with Designing and Implementing Industrial HMI Products

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Abstract: In this article, we outline our experience in embedded Human Machine Interface (HMI) development and design throughout the latest decade. We share some of our insights as to how to solve the fundamental challenges of creating embedded HMI products.

Keywords—*Human Machine Interface (HMI); Graphical User Interface (GUI) Design; GUI Development; Product Development; End-Users; Cross-Disiplinary Teamwork; Embedded Products.*

I. INTRODUCTION

Often times, creating embedded Human Machine Interface (HMI) products becomes a struggle of compromises between Graphical User Interface (GUI) designers and GUI developers.

Focusing solely on your own domain and goals will create tension with other domains, and ultimately lead to subpar embedded HMI products. The silo mentality becomes a major obstacle on the way to a successful product: GUI designers focus only on creating a stunning design while GUI developers focus solely on developing impeccable software, each thinking that theirs is the only way of creating the product.

What the individual domains must understand is that they are all working towards a common goal – a great product. You cannot create a successful product without a great end-user experience. If end-users do not like the product, they will not buy it. Hardware choices, software development, and GUI design all affect the end-user experience and thereby the product success, thus requiring these domains to work together for the common goal.

II. THE THIRD SPACE – GREATER THAN THE SUM OF ITS PARTS

Within research, we find the conceptualization of *spaces* in Bhabha [1]. Bhabha argues that domains of knowledge can be regarded as a space with their own distinct way of thinking,

expertise, and methods. Applying this within the HMI field of theory through Suchmann [2], domains such as embedded GUI development and embedded GUI design can each be regarded as domains of knowledge – equal to Bhabha's spaces. Both have inherent subdomains, but in our experience, there is a natural split between the two.

To create a successful embedded HMI product you need capable developers and designers within each space, but Bhabha furthermore, argues that once spaces meet, a hybrid space evolves; a *third space*. In this third space, the combination of skills highlight the required insights for making the best decisions with the common goal in mind.

A successful product is not created in isolation of each space, but rather in the interplay between the spaces, thus underlining the importance of the third space. Utilizing the third space correctly, and optimizing the output of it, requires a significant amount of alignment and teamwork. The third space enhances the exchange of knowledge between spaces when questions, challenges, reinterpretation, and renegotiation of product requirements inevitably arises throughout the product development process.

Combining spaces and obtaining an operative third space is not without issues, as pointed out by first Suchmann [3] and later Muller & Druin [4]. Every space has its own knowledge and practical way of working, which is rarely well defined. In praxis, this is highlighted by the extensive methods for requirement analysis needed in order to create products that both meet the end-users' needs and has commercial success.

A. *Aligning the Team under a Common Goal – Discuss and Challenge the Product Requirements*

Within the HMI field, every problem has tens or even hundreds of different solutions. Some are not technically feasible, some ruin the end-user experience, and some will lower the

commercial viability due to economic impact. A single problem can be solved in many different ways depending on the spaces you involve. Should

- the hardware design be adjusted to enable the software developers, and designers to meet requirements easier?

Or maybe it is better, if:

- the software developers spend time on a custom solution, so that the hardware set-up can stay the same?

Or could it all be solved, if:

- the design team would rethink this particular feature, and reuse some existing components or widgets?

Buchanan [5] argues that all problems are unique and wicked in their own way, making it nearly impossible to make a generalized approach for all problems. Only through understanding the usefulness of each other's space, as in Bhabha's third space, is it possible to discover the best solution for a particular problem. For example, if a minor adjustment, insignificant to the design team, can save the software team hundreds of hours it might be the best route. Just as if the software team could add another screen or component here, it would significantly reduce the menu complexity for the design team.

To discover the best solution, the different team members must engage in a cross-disciplinary conversation and continually discuss and renegotiate the product requirements when problems arise. Alternatively, you risk spending unnecessary time on solutions that could be expensive, shortsighted, and foster new issues in the future.

III. LEARNINGS FROM A DECADE OF EMBEDDED HMI DESIGN AND DEVELOPMENT – TEAMWORK AND ALIGNMENT EXEMPLIFIED

Through a decade's experience in the embedded HMI design and development industry, we have gathered valuable learnings for creating successful embedded HMI products in cross-disciplinary high-performance teams. To illustrate these learnings, we walk through one specific lever you can use to facilitate alignment within the team, and one case example of a great third space result. This is to demonstrate the gains of;

- focusing on aligning multiple spaces under a common goal,
- and nurturing a teamwork culture within a product development team.

A. Alignment – Appoint a Product Owner and Establish the Right Mindset within the Team

For all embedded HMI products, the end-user experience must be at the very core of the whole process. Nothing else can singlehandedly deliver the same results for your product, than making sure your end-users – your customers – are satisfied with the experience your product gives them [6]. The focus is the same across all spaces in the product development process.

Hardware choices affect the end-user experience; if the hardware limits core functionality or frequently breaks down during operation, the end-user will look for other ways to solve their problems. GUI design choices affect the end-user experience; if features does not enable the end-user to solve the task at hand, or the GUI is not structured and presented in a simple and intuitive way, the end-user will look to your competitors for other options. Software implementation affects the end-user experience; if the performance is subpar, or if user requirements are not met, the end-user will not take your product seriously.

Gathering the right end-user insights and defining the right end-user requirements is an entire discipline in itself, which we will not address in detail in this article. It is, however, important to note the difference between *end-users* and *customer* in our specific consultancy context.

- End-users are the people that will be using your product.
- The customer is the buyer of our services and owners of the product.

In our experience, establishing a clear Product Owner early in the product development process is a god way to ensure alignment across spaces. The Product Owner's primary responsibility is to maintain the speed of your operation by gate-keeping functionality, look and feel, and evaluating any new idea coming into play.

B. An Effective Product Owner

The most effective Product Owners are those who understand their end-users and their importance, and has some understanding of the technical side of things. A strong Product Owner has a strong executive mandate and should be able to answer questions, verify iterations, and prioritize tasks singlehandedly and continually. The Product Owner's most important tool is a locked Business Case.

C. In Conclusion

To reiterate the initial point of this paragraph, it is important to note that even though the Product Owner is responsible for defining the end-user requirements for the product, all team members must make sure that their deliveries support the end-user requirements. Otherwise, it will have consequences further down the line.

A way of starting the alignment across the team, that does not require much effort, is to print out the vision of the product, hang it on the wall and use it as a visual reminder of what you as a team aim to achieve. This should help you align from the start, settle arguments, and keep you on course with the core functionality along the way.

IV. TEAMWORK – MUSIC PLAYER EXAMPLE

To look at a concrete example on how teamwork can drastically change the solutions offered to a specific problem, we follow the transition from GUI design to final GUI implementation in the example below.

Take a music player demo GUI (see figure 1.) on a microprocessor, where the customer wants a nice, smooth video when starting a piece of music, creating a cozy experience for

the end-user. This particular hardware is not suited to run full-screen video with an acceptable framerate out of the box. Nevertheless, this is the customers' requirement.

A. Finding a Solution in Separate Spaces

The approach for solving this task can of course be found within each of the spaces:

- The hardware team could alter the hardware by adding the required hardware for running a video file. This would of course require another hardware loop, which is time-consuming and increases the cost-per-unit and will impact the Business Case of the product.
- The GUI design team could try to redesign a work-around and avoid video all together, or maybe renegotiate the requirement with the customer. This, ultimately, will not end up as impressive as originally envisioned by the customer, who might be left disappointed. This does not really play well with our end-user experience focus as outlined earlier.
- The GUI development team could of course lower the video quality, by stretching a low-resolution video or lowering the framerate. Again, that would give a less impressive end-user experience.



Fig. 1. The four pictures above illustrate the motion on-screen in the specific embedded HMI example.

None of the spaces is able to offer a great solution on their own, only offering compromises that would either;

- prolong the project timeline,
- increase the cost-per-unit,
- or provide a less satisfactory end-user experience.

Even though none of the spaces were able to solve the issue on their own in a sufficient way, the same people came up with a great solution when they joined forces in a third space.

B. Finding a Solution in the Third Space

Utilizing the third space through cross-discipline collaboration, the team was able to solve the issue in a simple way.

Our GUI designers and developers got together and discussed how to implement the proposal from the design team. The developers noticed that most of the important motion in the video was taking place within a relatively small part of the screen, and proposed that only running video in a limited part of the screen, would make it possible to achieve a good framerate. This would of course require the design team to cut out the surrounding images in a specific way, but as the designers were part of the collaborative session, it was easy to understand what was required for the final solution.

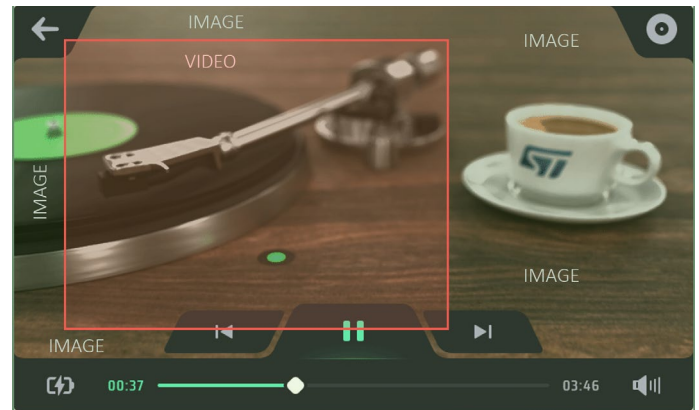


Fig. 2. The picture highlights the area of movement on screen.

C. The Third Space Delivers a Solution That Meets the Common Goal

The result was a music player screen, where the video and surrounding images are seamlessly layered. This creates a convincing illusion, that the music player is actually running a full-screen video, satisfying the customers' requirement of a smooth and cozy experience for the end-user.

Technically, this is far from running a full-screen video, but the specifications of the video in itself, is not what excites the end-user – it is the experience that the motion on-screen gives that makes an impact. The end-user experience imitate that of a full screen in motion and the desired experience is achieved.

Should you only collaborate when issues are tough? Of course not! Keep discovering easy solutions along the way by using the Third Space throughout the project. Often times the most important discoveries you make, are the ones you did not know you needed to discover.

D. In Conclusion

To sum up this chapter, the experience we have gathered over the latest decade working in the field of HMI with embedded GUI development and design, we know that the third space teamwork is essential when maximizing hardware performance and end-user experiences.

The music player example illustrates that point, and as developers and designers learn to understand each other, the teamwork becomes progressively more effective. In the music player example, developers could not find a satisfactory solution alone, neither could the designers. When joining forces, however, they quickly came up with a cost-efficient solution. With strong alignment within the team, they were able to implement the solution quickly – no explanations necessary.

V. LEARNINGS TO TAKE FROM THIS ARTICLE

To conclude this article concerning the HMI field and the challenges of developing embedded HMI products here are highlight of the points we have made.

We addressed the matter of collaboration between developers and designers, as this is, in our experience, the key to mastering this complex third space. Developers alone cannot create great embedded HMI products, neither can designer, not even when they work together in different spaces.

The solution is the third space, where the sum of the two spaces becomes more than their parts, as the developers and designers empower the work of one another. We saw a specific example of this with the music player case and earlier in the article, we delivered some hand-on advice as to how to establish this third space:

- Align the team under one common goal: Achieving a great product with a great end-user experience.
- Establish a strong Product Owner with a locked Business Case and an executive mandate.

- Encourage the different spaces to work together, not only for specific issues, but as a continuous process throughout the project.

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