Analysing Fluid Interaction across Multiple Displays

Richard Morris, Paul Marshall and Yvonne Rogers
Open University
Milton Keynes, UK

ABSTRACT

Interaction with groups carrying out tasks across multiple displays and devices can be complex. Users have to switch their attention from controlling one device to another while continuing with their ongoing activity and conversations. This raises questions about how to support and evaluate interface design which facilitate fluid interaction. This paper provides a nascent framework of fluidity as a way of analysing interactions across multiple displays and tasks. Three fluidity heuristics are outlined illustrating how they can be used to aid the design and evaluation of interactions with multi-display systems.

1. INTRODUCTION

Shareable and personal devices are providing designers with new opportunities for creating a wide range of rich technology-augmented spaces that can support collaborative working, learning or playing. However, there are significant challenges in doing so: infrastructure and interfaces must be developed to share information, representations and interactions across an increasingly diverse ecology of devices. Furthermore, this diversification leads to a combinatorial explosion of factors that the designer must take into account when developing such a system for a user group, task or context. Such factors include the number of devices available to the users; what kinds of information should be shared and what should be private; what mechanism or metaphor should be used to move information between devices; and in what orientation should shared displays be placed. As pointed out by Tan *et al*. [6] there is a dearth of evaluation methods, tasks and metrics that could be used in evaluating multi-device collaborative environments.

A key problem is managing the flow of work between displays, be they personal/small or shared/large displays, specifically how one addresses the other displays, and transfers work, from the one currently in use. Will they be controlled through gestures (if touch-enabled) or menus? Will animation help in reducing the cognitive overhead of switching between screens? How will the users be given feedback or retrieve their work if something goes wrong? Our research seeks to help designers address these questions by providing conceptual tools of analysis.

2. BACKGROUND

Fluidity is a concept that is increasingly being used to describe a desired state for new forms of interaction. This would be manifest in ways such as users being able to move smoothly between displays, devices and tasks without having to exert too much cognitive effort. In particular, users should not have to constantly switch their attention between control operations and the goals of the task. The aim is to enable a group's actions and interactions with a system to be invisible (cognitively), ordinary and to flow smoothly. While this is an important goal, the concept has yet to be operationalized so that it is possible to assess the fluidity of the diversity of interactions when using multiple displays.

Fluidity has been used to describe the various transitions that are needed to enable collaboration [7] and the obstacles that can hinder interactions, such as dialog boxes popping up [1] and as Isenberg *et al*. [3] have noted that these guidelines can be expressed in the positive sense of supporting high-level cognitive aspects of a task without forcing the user to deal with low-level objects. The benefit of such fluidity of interaction is that users can bring more of their attention and creativity to bear on their ultimate goals, or other demands such as collaboration, leading to more productivity and higher quality work.

One approach to fluid interface design is in terms of reality-based interaction [4]. This seeks to model real-world themes and to reduce the gap between a user's goals and the means of execution. The real-world themes are naïve physics, body awareness, environmental awareness and social awareness. By designing interfaces, based on the rules of these dynamics, the need for low-level operational expertise is reduced, affording the user the opportunity to focus on higher-order goals and more focused creativity. Also, it should be easier for users to return to where they were previously when interrupted, as the cognitive effort of getting back into the framework of the interaction is reduced. This also affords the benefit of encouraging reflection and viewing the bigger picture for a fresh perspective or learning. As these interfaces provide more natural interaction it is also hypothesised that they will lead to better social interaction when working in groups.

It follows that multiple display and device systems should not be unnecessarily complicated, and should employ reality-based interaction where possible, except where certain explicit trade-offs are made to add further functionality. Jacob uses the analogy of the character Superman: when he is performing simple tasks he walks and talks like a regular human, but when the situation requires it he uses his powers to increase his efficiency in completing his task.

The concept of fluidity is appropriate for analysing the complex development of multi-user, multi-device interactions. One challenge is to provide a way for users to get the most out of the technology at novice and expert levels. Too little help or signposting and the novice cannot engage with the system: too much and the expert user becomes frustrated. Guimbretière argues that dialog boxes, tool selections, object handles etc. are "inevitable to provide complex functionality" [1, pg. 3]. His FlowMenu [2] gives visual feedback without permanent menu bars or palettes by using a pen-addressed radial layout menu, which encircles the pointer whenever the menu is summoned but also allows experts to use gestural memory without feedback.

However, collaboration is not governed solely by the quality of the interaction that the user has with the interface but also the interactions between the user and others, and other users and the interface. A successful collaborative task may depend on the ability of individuals to work singly in personal spaces while carefully choosing their interactions with the other users at various stages. Given the intricacy of group interactions, another challenge is to design computer interfaces which can support them while being simple enough to use that all group members can contribute effectively.

3. FLUIDITY HEURISTICS

Below we propose three heuristics that can be used to analyse how systems of multiple displays and devices are able to support users in achieving their task goals. These are ready-presence ratio, cognitive focus maps and interaction matrices.

3.1 Ready-presence Ratio

The first heuristic, *ready-presence ratio*, is based on the idea of measuring interactions when moving between subjective states of involvement: our starting point is Heidegger's well known concepts of readiness-to-hand and presence-at-hand (see also [8]). The canonical example of using a concrete tool such as a hammer exemplifies what it means to switch between 'present-at-hand' and 'ready-to-hand' depending on the user's awareness of the hammer. When hammering away at a nail one is often not aware of the hammer as being distinct from one's own arm and hand or part of our 'totality of involvements'. The tool becomes an extension of ourselves in the expression of our task. In this state the hammer is ready-to-hand. However, should the hammer break or hit our thumb we would become aware of the interruption to our task and the hammer would become present-at-hand.

In terms of user interactions, we employ this idea to conceptualise when a user is interrupted in the flow of completing their task. *Higher-order* user actions are those directly related to dealing creatively with a task; those which are directed at dealing with the state of the computer are *lower-order*. Expressed as a ratio of higher- to lower-order action, fluidity is essentially the property of being in a higher cognitive state and focused on the task, not the tool. Thus:

$$fluidity = \frac{higher\text{-}order - lower\text{-}order}{total\ operations}$$

The key feature of fluidity is that it is a measure of the proportion of task-specific actions and cognition. For example, if a user is to draw a circle and label it with text, they might perform 15 operations dealing with low level aspects of the machine such as opening the program, selecting the appropriate view and palette, selecting the right tool, and changing to the text tool, and the operations which are related to the higher-order goal such as drawing the circle or typing the text would amount to two. This would give a fluidity score of F=-0.77 (2-15)/17).

Compare this to performing a similar task on a drawing surface such as Guimbretière's PostBrainstom interface [1]. The lower-order task would be picking up the pen, but drawing the circle and writing the text would be done directly as two higher-order goal-centred operations, giving a fluidity score of F=0.33. Compared to the previous example the fluidity score F is large, and in a more positive direction, indicating that it leads to a more fluid interaction.

As well as comparing across interfaces, this heuristic is also intended to be applied across experience levels. Supposing that a new interface is highly reality-based then experience level should have less of an effect on the F score. Any difference in F could indicate that experienced users are employing shortcuts, which could indicate an area for further study.

When defining and analysing fluid human-computer interactions, therefore, it is important to take into account the users' level of expertise with the task and the technology. It may be possible to design interfaces that are fluid to use by experts for a task but not for novices (e.g., a games console). There is a distinction also between expertise at lower and higher levels of action. For example, being an expert typist may not automatically confer an advantage to a player in a strategy game if they are not also expert at the higher-level goals and conventions of the game. Conversely, an expert tennis player might be at a disadvantage in a game of Wii Tennis against someone who has more expertise in using the WiiMote controller.

3.2 Cognitive Focus Maps

The second heuristic, *cognitive focus maps,* graphically project *cognitive focus* over time in an interaction. Figure 1 (top) shows an example of how an experienced user might interact with a complicated application like AutoCAD. After launching the application the user can begin outlining whilst in a high-order cognitive state and considering their design goals. Next the user has to specify a certain variable and a specific dialogue must be sought where the user can input a variable e.g. wall thickness, or material type. Because the user is experienced and knows what to expect they can interact smoothly and without feedback or cogitation. Like Jacob's Superman the architect must make a small but useful interruption to their flow to make an explicit input.

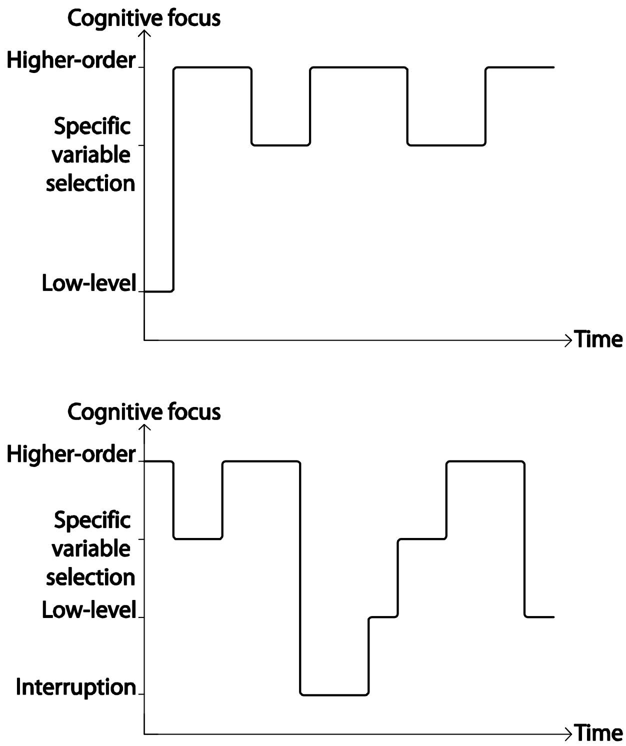

Figure 1. ***Cognitive focus*** **over time in an interaction for (top) an experienced user and (bottom) during an interruption.**

Figure 1 (bottom) describes a difference scenario where an individual is sharing photos with someone else using a tabletop display such as a Microsoft Surface with an inturruption in the middle of the task. The figure is intended to highlight the difference between the users' experience of interacting with the table at times when low-level objects must be dealt with, such as waiting for data transfer or resuming the machine after it goes into standby during the interruption, and being able to operate on the higher-order goals of the task such as the actual photo sharing and discussion.

Following the interruption and resuming the machine from its standby state, a short period of time is spent by both users looking back over the photos in the stack. This is an example of how the user experience can be 'buffered' when moving back into an interaction, whereby remembering the state of the interface before the interruption and the position of photos relative to each other can aid the users' memories and help in resuming the conversational thread. This could be enhanced further by, for example, replaying recorded audio from before the interruption to assist recollection.

3.3 Interaction Matrices

Our third heuristic, *interaction matrices*, describes the interactions between groups of users with various interfaces. Supporting a collaborative design task requires the ability to move from working one-on-one with the computer, to social interaction, and multi-user interaction with the interface. In this context, fluidity impacts on the quality of an interaction that extends beyond the user-interface, as the properties of interaction 'inside the interface' can have an effect on social interactions 'outside', collaboration and the flow of ideas. Thus a user who is experiencing a fluid interaction with an interface will find it easier to take part in the social level of interaction, theoretically leading to better collaboration.

Figure 2 depicts several modes of interaction using a short-hand notation, or interaction matrix, taking the form {('outside' interactions):(interface interactions)}. Situation 'A' is the simplest: one user and one interface are having one interaction {1:1}. In 'B' there are three users all interacting with both the interface and each other. The dotted lines on the interface are meant to denote that there are different ways to divide the work area. All three users could be sharing the one interface together {(3*3):1} or they could be working in separate spaces and sharing between each others' spaces {(3*3):(3*3)}, or simply working on their private spaces alone {(3*3):(1*3)}. In 'C' the users are interacting with each other but one user is mainly interacting with the interface.

Situation 'D' is a special situation where an expert user is interacting with the interface in a way the other group cannot and the output of this interaction is used by the group {(3*3):1:1}, such as when using a facilitator.

The interaction matrices can be used to describe how different user / interface combinations can lead to different design goals and expectations about fluidity. By separating the interaction matrices inside and outside the interface a clearer understanding can be reached of the true nature of interaction occurring. All these situations have different modes of interaction, but a fluid interaction between the user and the interface always benefits the entire goal, whether the user is in a group, alone, novice or expert. In 'D' the user is required to be highly expert as creating real-time visualisations of discussions is a complicated task. However, in 'B' simpler interface actions should be used to ensure all users have a similar level of control. Also, the interface should avoid dialog boxes, as it may be unclear which user it corresponds to. In 'A' the user can be novice or expert, depending on their level of experience and the necessity for complex 'superpower' operations. 'C' is in-between as the main user can fall on a range of expertise but other users may wish to input directly.

4. USING THE HEURISTICS

Our fluidity heuristics are intended to assist both in the design and evaluation of interfaces and the various types of interactions, and group modes, by expressing different aspects of the fluidity of these interactions. The ready-presence ratio is intended to focus the designer on the way a user experiences readiness-to-hand, when focused on the higher-order goals of the task, and presence-at-hand – seeing the user and the tool (interface) separately. This heuristic can be used in tandem with the guidelines produced by other authors (e.g. [1],[5]) to assist understanding of users' shifts in conscious awareness at key points. It assists in evaluation of the overall interaction quality and in comparing across interfaces or user experience levels.

The cognitive focus map can help in highlighting the transitions between users' states of awareness and 'presence' in the interaction, to help identify key areas in the design of the interface to enhance the user experience. The area under the graph also gives an evaluative indication of the overall fluidity of the interface, where a larger area indicates greater time spent in goal-focused states of mind. By adjusting for the total length of time of the interaction, it could be possible to analyse interactions in a way which is less skewed by experience level, in terms of dealing with dialog boxes etc., than the ready-presence ratio.

The interaction matrices heuristic can be useful in designing an interface by highlighting the ways that groups and single users can interact with it and with each other. By separating the interactions inside and outside of the interface it can be seen where design goals, such as removing visual clutter, will be most effective. It also provides a shorthand way of expressing specific interaction modes to help facilitate discussion and evaluation.

To illustrate how these heuristics can be used together to analyse how fluid the interactions are for users moving between displays consider the scenario of how scheduling work meetings could be enhanced through having a system of shared and personal displays. People in organisations use shared software calendars to arrange projects, meetings and schedules of work. However, it can be very time consuming to arrange a meeting, especially when it depends on email response. If a shared calendar application was made available whereby a large touchscreen could display an overall work schedule (i.e. a Gantt chart), representatives from each team could work either on the overview schedule or on small tablet or handheld devices to make fine-scale adjustments or to rearrange outside commitments around the emerging work schedule. The application could be analysed by using the three heuristics above. The interaction matrices would help in describing the different permutations of interaction possible in this

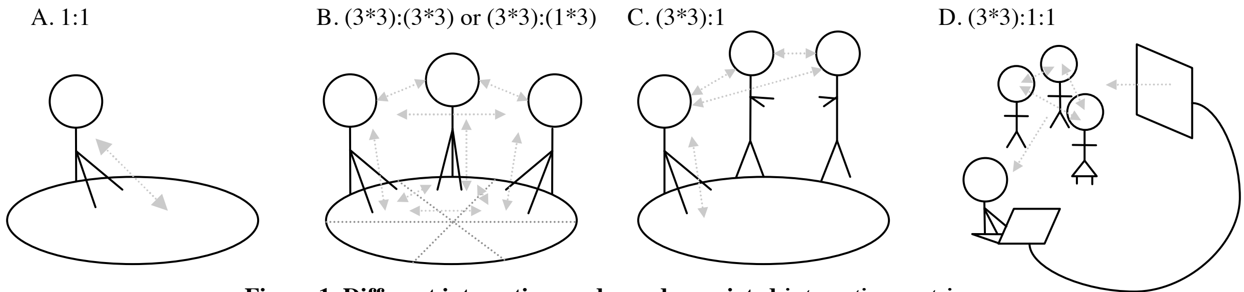

Figure 1. Different interaction modes and associated *interaction matrices*.

arrangement, i.e. whether the users are all interacting with the large screen, their small screens or any combination between. This could assist a designer focus their methods for moving data between screens at the most appropriate times.

The fluidity of the interaction could be assessed for each individual user using the ready-presence ratio. This would give an impression of how different styles of interface would support or hinder fluid interaction for any given situation. For example, when working on a small personal screen the user may have to make more low-level actions due to the size constraint of the interface, but this may lead to more rapid progression of the overall goal of organisation on the main chart.

The cognitive focus maps can be used to analyse the interaction over time and to bring attention to key moments, such as when a user switches between working at the big screen to their individual screen, or to help design ways for users to collaborate or resume work after an interruption. Explicitly considering where the user is focusing their attention at certain points can help the interface designer support key actions.

One problem which may arise when collaboratively creating schedules is that a clash may arise. Being able to work on their own sub-schedules individually, the team members involved can work in parallel to make fine adjustments and compromise to make the overall schedule work, and this could be expressed in an interaction matrix. Key points in this interaction would be the identifying of the clash on the main screen. Then the users would have to use the interface to edit their schedules individually and then return their change to the main schedule. How this is accomplished through interface design choices can be readily assessed using the ready-presence ratio and cognitive focus maps. Experimental studies could then be performed on different interface prototypes to evaluate their fluidity.

5. SUMMARY

We propose that in order for groups to effectively utilise multiple displays by switching work between screens, interfaces and interaction styles and be able to do so without interrupting the flow of their ongoing tasks, the interactions have to be fluid. However, fluidity can be a nebulous term that is difficult to define. In this paper we propose three heuristics intended to aid in the analysis of interface and task interactions, which can provide an indication of fluidity and clarify the processes involved. In so doing, they can highlight how to design for users so they can easily transition between multiple interfaces, tasks and conversation whilst keeping their creative thoughts and expressions ‘flowing’.

6. ACKNOWLEDGMENTS

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