Interactional Traps: a Case Study on Digital Libraries

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Abstract: We define an interactional trap as a situation in an interaction in which a user believes that their objective is not achievable even though it is or, conversely, believes that it is when it is not. Interactional traps are not solely a consequence of computer system design, or just a result of user actions, but arise through the interaction between the agents. We present an interaction framework that allows us to describe such features in terms of the communicative events that make up the interaction. This provides a way of thinking about the interplay between computer system design and user properties, such as what the user knows or how they perceive and interpret information. We illustrate the approach with examples of use of digital libraries.

Keywords: interactional trap, interaction framework, digital library, HCI, common ground.

1. Introduction

Breakdowns in an interaction are rarely due to simple computer system failure or user error, but are most commonly a result of interplay between the two. Frequently, the point at which an error manifests itself is some time after the point where conditions were set to make the error likely; Reason (1990) refers to such conditions as 'latent errors'. Also, in many situations, a breakdown is not the result of a single point of failure, but of a sequence of events that accumulate to create an unwanted situation. Such errors have been studied within the safety critical systems community (e.g. Hollnagel, 1998), but relatively little within mainstream HCI. We are developing an Interaction Framework that aims to support reasoning about properties of interaction by abstracting away from details of user and device to focus on the interaction as an entity in its own right.

The focus of this paper is on 'interactional traps'; these are situations in which a user acquires, and acts on, incorrect beliefs about the achievability of their objective. The consequences of these are sometimes simply inefficient interactions and at other times, failure to achieve high level objectives.

The examples in this paper are based on video analysis of protocols taken with three users, working with various digital libraries.

2. Interaction Framework

Our framework for understanding interaction is composed of several forms of description of the interaction which contribute towards overall descriptions of general interaction properties. We believe it is important to understand these to achieve effective design and evaluation. This develops from original work by Barnard and Harrison (1989), who proposed Interaction Framework (IF) as an approach to considering the conjoint behaviour of users and computers within an interactive system, focusing particularly on interaction trajectories (i.e. traces of communicative events within an interaction) and their properties. It is also a development of work by Blandford, Harrison and Barnard (1995). This section briefly describes the components of the interaction framework that are central to the subsequent discussion of interactional traps.

2.1 Fundamental Interaction

Fundamentally, we consider interaction occurring between *agents* in a *system* via communication *channels* – interaction is in the form of *events* communicated between agents along these channels. IF can be used to consider interactions at different

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levels; for the purposes of this paper, however, we work at the level of a turn within the interaction.

Interaction occurs for a reason; therefore, at least one of the agents involved in the interaction has some set of explicit and implicit *objectives*. An explicit objective is usually one which an agent actively tries to meet *e.g.* finding a book relevant to their current topic of work. An implicit objective, on the other hand, is one which is not usually actively being pursued, but which can become an explicit objective due to some event *e.g.* when searching for books on model railways (their explicit objective), the agent may come across books on voltage transformers which are relevant to an implicit objective they had. They may then take up the search for information on voltage transformers as an additional objective.

Furthermore, each agent has state, as does the whole system. System state is made up not only of agents' states, but also the communication channel configurations and the constraints on these channels. Systems move from one state to another due to the initiation of some event – a transition event. For each state there is a state potential for each agent involved in the interaction. This is the set of events which the agent could issue. This does not necessarily mean that the agent is aware of all of these possibilities, but that they exist, in principle.

2.2 Traces of Interactions

The *trace form* builds on the fundamentals to describe *interaction trajectories* which are partially ordered sets of events constituting an episode of communication between agents attempting to meet objectives. For example, in searching for a text in a collection (an objective) there is a sequence of events for a user attempting to find the text. We are interested in trajectories that do not meet objectives efficiently, and the reasons behind this.

2.3 Symptoms of Interactions

Symptoms categorise a trajectory in terms of whether the trajectory was *canonical* (most efficient for achieving the objective), and if not, what the symptoms of interactional *trouble* were. Troubled trajectories do not meet objectives, or do not meet the objectives in the least convoluted manner. For example, mistakes may be made by the user in issuing an event which leads to the interaction involving a detour to return to a point from which the objective can be met. Reasons for non-canonical trajectories include *blind alleys* (where an agent proceeds for some time before they realise that they are not progressing towards their objective and so must *restart* the interaction), *interactional traps* (where an agent has incorrect beliefs about the achievability of their objective), and *interactional detours* (where an agent performs interaction which does not directly move them towards their objective). The point at which the trajectory moves away from the most efficient trajectory is called the *point of deviation.*

2.4 Causes

Once symptoms of interactional trouble have been identified *causes* are used to suggest explanations for the trouble. At this point IF can use hooks to other theories and modeling techniques to provide explanations for trouble occurring. For example, models of human cognition such as ICS (Barnard & May, 1999) could be used to suggest the relationship between users' goals (related to their interactional objectives) and the structure of the information conveyed by the computer system. IF also provides some suggestions for causes of interactional trouble.

2.5 Properties

Finally IF considers the interactional *properties.* IF describes properties of the states and trajectories such as serendipity - happening upon relevant information. Such properties can be related to lower levels of the framework in order to inform both analysis of current systems and design of new systems. This paper is less concerned with properties than a particular symptom – interactional traps – and its causes.

So, IF models agents interacting together to achieve some non-empty set of objectives. Moreover, by grouping agents we can understand interaction at different granularities. The key is that we are interested in the trajectories – how agents get from one state to another.

2.6 Mutuality

As we will see, the primary cause for interactional traps is poor *mutuality* between the agents. While mutuality is not a central component of IF, it is important in this case. In interaction, agents communicate events along communication channels. These events attempt to communicate some information about the state of the agent. But issuing an event does not necessarily mean that the recipient will receive the event let alone understand and act on it appropriately. We draw on Clark's notion of *common ground* (Clark and Brennan, 1991), and in particular the interpretation of common ground used by Healey and Bryan-Kinns (2000), to develop the notion of event mutuality, or mutual understanding of events.

For an agent A issuing an event e intended for agent B we define five states of event mutuality that agent B could be in with respect to the event e:

State 0: B is unaware that event e exists.
State 1: B is aware that e exists.
State 2: B recognises e as being of a particular type.
State 3: B understands the content of e.
State 4: B understands what actions are associated with e.

In computational linguistics terms, mutuality states 1, 2, 3 and 4 correspond approximately to agent B recognising the existence, syntax, semantics and pragmatics of the communication. The loss of, or failure to develop, adequate mutual understanding between user and computer system is one of the themes that runs through the case study.

3 The Observation

The method used in this study has been to apply Interaction Framework to analyse interactions between users and various digital libraries. This study originated from a general interest in studying usability of digital libraries, and in particular testing the scope of Interaction Framework for this application domain. While analysing the data, one of the important features that emerged was that the subjects in the study often reached the conclusion that their objectives were or were not achievable, when a neutral, knowledgeable observer would know that this was not the case. These 'interactional traps' and their causes are the subject of this paper.

The study is based on protocol analysis of video of three users working with digital libraries to achieve their own personal objectives. A digital library is a structured repository of electronic documents, often including multimedia; for example, the New Zealand Digital Library (NZDL) includes music collections (McNab, Smith, Witten & Henderson, 2000) and oriental poetry as well as more traditional text and graphics. Libraries are typically organised in ways that are intended to facilitate access, and include search and browse facilities.

The three users in this study were two first year PhD students (referred to below as 'A' and 'B') and one experienced academic ('E'), all computer scientists. A and B were recruited as subjects specifically for this study. Their task was defined as obtaining at least one paper on their own research topic to help with their literature review, using their choice of libraries from a given set easily accessed via bookmarks). They were also asked to think aloud while working. They were provided with a little information about each library, as shown in Table 1.

As will emerge in the discussion below, the lack of clear limits on what could be accessed (because of the subscription type held by the institution) was a contributing factor in many traps.

ACM Digital library www.acm.org/dl/	Full text access only to journals and magazines (not conference proceedings)
IDEAL www.idealibrary.com	Access only to articles prior to 1998
NZDL www.nzdl.org	Full text articles
EBSCO www-uk.ebsco.com	Full text articles
Emerald www.emerald-library.com	Full text articles
Ingenta www.ingenta.com	Full text articles

Table 1: bookmarked libraries for users A and B.

E was planning to search for articles on particular topics to help with writing academic papers, and volunteered to do this with a video camera running, and to 'think aloud' while working on her self-defined task. Consequently, she used digital libraries of her own choosing, and did not have explicit information about limitations on access.

Users A, B and E worked with the digital libraries for 57, 62 and 80 minutes respectively. The video data was then transcribed, including speech and some description of interaction between user and computer system. Extracts from these transcripts are used in the following sections as source materials for examples. Short debriefing interviews were then conducted with the users to clarify our understanding of certain aspects of the interactions. Table 2 illustrates the notation used in the transcripts.

Notation	Use
`Blah`	Vocalisation by subject
`[> blah]`	Action: input to computer 'blah'
`[< blah]`	Action: computer output 'blah'
`[- blah]`	Current computer state 'blah'
`[blah]`	Note 'blah'
...	Cont. of vocalisation across action

Table 2: Transcript notation

3.1 Users' Objectives

All three users had one main objective: to find information from digital libraries relevant to their current work interests. User A described it: "my search is about electronic commerce. So I am looking for papers." User B was looking for material on knowledge management, text mining and link analysis. User E required information on digital libraries, cognitive modelling and usability of Artificial Intelligence systems.

3.2 Agents in the Observation

For the purpose of understanding interactional traps, we consider the system as consisting of just two agents at any one time: the user and a digital library. This is a simplification; for instance, other analyses of the same interaction consider user interface and collection as separate agents, and treat each window as a separate agent (where the user is working with more than one window at a time – typically to allow a large document to download in the background while continuing to work in a separate window).

3.3 Summary: User A Interaction

User A was interested in papers on electronic commerce. As she started working, she spent a while browsing the web home page before selecting a link from the bookmark list. She selected the ACM digital library, and spent some time reading through the introductory page. She then searched for 'the best of electronic commerce', but seemed rather confused by the results returned. She selected an alternative search mechanism and repeated the search. She found various articles that were "interesting" but did not print them. Although she limited her search in ACM to "journals only", conference articles were listed among the search results; when she tried to download one of these articles, she was asked to enter a user name and password, which she did not have, resulting in an authorisation failure.

She moved to the computer Science Technical Reports link in NZDL, and got over a thousand hits on her search. She reformulated her search several times, and still too many items were returned. Eventually, she found an article she wished to view and download, but failed to download it. She then moved on to EBSCO. When her search results were returned, she commented that "this is more readable than from other libraries". She successfully found, saved and printed one article.

3.4 Summary: User B Interaction

User B did not have previous experience of using Netscape, so he starting by browsing Netscape pages before connecting to ACM digital library via the bookmarks. Before specifying the search terms, he spent some time "trying to understand how to make the search". When searching the ACM library, he did not restrict his search to journals only, and consequently received many 'hits' that were conference proceedings; like user A, he got authorisation failure when he tried to print any of these.

Although new to Netscape, user B was a relatively sophisticated user of information retrieval systems. For example, he understood how to use quotation marks selectively in search queries and also resorted quickly to using two browser windows so that he could continue working in one window while a document was downloading in the other. Using this strategy, he explored the EBSCO library, then NZDL, then Ingenta – continually flicking from one window to the other as pages were loading. One apparent consequence of this is that his behaviour was more reactive than that of the other two users: he appeared not to form clear beliefs about the state of the system, but to simply respond to whatever was currently displayed; consequently, interactional traps were less evident in his interaction than in those of the other users, but – conversely – the interaction appeared relatively unstructured and haphazard.

3.5 Summary: User E Interaction

User E had several objectives as discussed previously. In meeting these objectives she used three libraries: ACM, IDEAL and the New Zealand Digital Library (NZDL). These were used in a relatively orderly sequence of ACM, followed by IDEAL, and finally the NZDL. The search objectives were repeated to some extent with each information source as opposed to meeting each objective in sequence.

In detail, she spent most of her time using the ACM DL. Any articles she found that seemed relevant were printed for further review. She started with a search for "digital librar", which yielded no matches, then for papers on cognitive modelling, using a strategy of searching for particular names (such as "Rasmussen" and "Hollnagel"), which also yielded no useful results. Similarly, a search for Artificial Intelligence yielded no matches, for reasons discussed below. She then switched to browsing various collections, with mixed success. Overall, this user's interaction was the most fruitful, and by the end she had printed about a dozen articles.

4 Interactional Traps: Examples From Data

Within the data, many examples of interactional traps can be identified. Inevitably, those that involved the user incorrectly believing that something was possible were relatively short-term, as the user eventually realised that the objective was not in fact achievable. Examples where the user incorrectly believed that an objective was unachievable resulted in the interaction concluding without a satisfactory outcome. In all cases, it should be noted that the overall task objective (of retrieving appropriate documents on a particular topic) was achieved through the achievement of sub-objectives such as familiarising themselves with the type of material and search facilities in a new library, locating documents that satisfied their criteria, and viewing or downloading a particular document. Traps occurred for these different objectives within the overall interaction.

4.1 User A: Authorisation Failure in the ACM Digital Library

The first example we consider involved user A failing to download a conference paper from the ACM digital library, as shown in the following:

```
[- ACM DL search page]
I will search in ‘all journals and
proceedings’ … no: ‘journals only’
[>selects ‘journals only’ to limit search]
[> clicks on ‘search’ button]
[<list of matches returned (contains both
journals and proceedings)]
 […browses through search results and
selects an article from the list]
[>clicks on ‘full text’ button]
[<pop up window requesting user name and
password]
Ow. Yaa. You have to get a user name and
password because I haven’t registered.
```

Because the user had specified ‘journals only’, she expected all returned results to conform to that limitation, and therefore to be accessible as full text. Due to a bug or misclassification in the library (which we believe to have been temporary), items were listed that could not be downloaded. While it was, in principle, possible for the user to see that an article was listed as being in a conference proceedings, she did not notice this.

In this case, the point of deviation occurred in the event where the user agent communicated “journals only” to the computer system – information that was apparently not received by the system. Subsequent events include system displaying list, user selecting item, system displaying abstract, user selecting full text, system displaying authorisation box. In principle, the information about the article being in a conference proceedings was available to the user, but it was not communicated due to the earlier deviation between the computer system representation of the objective and the user’s.

4.2 User A: Failure to Download in NZDL

Later in the interaction, the user was working with NZDL, and had selected an article to view. She read from the screen: “expanding the text here will generate a large amount of data for your browser to display” (see Figure 1). Taking the warning as implicit advice on something to avoid, she then typed ‘1’ and selected ‘go to page’. The result was that only page 1 was displayed. Some time later, she commented that “I am looking for the option how to download, not just explore it”. After 6.1 minutes in total, she had tried every option she could find for downloading the entire article, and concluded that “I’ve tried all, but I can’t download”. This is an interactional trap regarding the design of the library: the user can only download and print pages that have been displayed.

Figure 1: Screenshot illustrating the warning message that diverted User A.

In this case, the point of deviation occurred when the user elected to view just page 1: at that point, the computer system limited the scope of what was possible in a way that the user did not recognise. Most of the subsequent 6 minutes of interaction was devoted to achieving an objective (downloading the article) that was not, from that situation, achievable.

4.3 User B: Authorisation Failure in the ACM Digital Library

Like user A, user B tried to download articles from conference proceedings in the ACM library, and was denied access; however, the cause appears to be different: while user A was aware that she could only access full text of journal articles, user B was apparently unaware of this (despite it being stated in the instructions to users), and had to have it pointed out to him by the experimenter after several abortive attempts to download conference papers.

In this case, the interaction between user and system started with low mutuality [the user was not aware of an important limitation on what he could download]. The subsequent interaction did not support him well in revising his understanding.

4.4 User B: Authorisation Failure in Science Direct

Another case of authorisation failure for user B occurred towards the end of his interaction, when he selected the ‘full text’ option for an article in Ingenta. A message appeared to inform him that full text was available via Science Direct, which he therefore selected. When asked to enter a user name and password, he supplied those he had been given for Ingenta, failing to distinguish between the two: when the experimenter interrupted him after over 2 minutes of entering and re-entering the Ingenta user name and password, to tell him that he could not download the file, he asked “Why?” The significance of the transition from one document source to the other in terms of access rights was not clear to him.

In this case, there was an important transition event, in which the user ceased to communicate with one library agent, and starts communicating with a different one, without that difference being made salient to him. This is a point of deviation between user and computer system; again, the subsequent interaction is inadequately signposted for the user to immediately grasp the significance of the transition.

4.5 User E: Failure to Find Digital Libraries in ACM Digital Library

The first example of an interactional trap for user E was failure to find any articles on digital libraries within the digital library (this despite the fact that the library contains both journals and conference proceedings on the subject). In the following transcript it is evident that the user’s familiarity with search formulation in general led her to manually truncate (or stem) her search terms from ‘digital libraries’ to ‘digital librar’. This resulted in no search results being returned. The ACM digital library allows the user to specify that the search engine should stem terms, but it assumes that the user has entered complete words for matching.

```
 [- ACM DL search page]
Terms such as digital libraries…
[>types ‘digital libraries’ into search
box’]
[< search box contains ‘digital
libraries’]
… seems kind of bizarre to look just for
titles, so… if I put libraries I’m going
to miss those with library so I’ll put…
[> changes ‘libraries’ to ‘librar’]
[< search box contains ‘digital librar’]
… exact phrase and try ‘full text’.
[………]
Oh, no matches.
```

The user did not find any articles on digital libraries in the ACM library through the entire interaction; she had apparently concluded that they either do not exist, or that they could not be accessed by such a search.

In this case, the point of deviation occurred where the user chose to manually stem the term; the system’s response of ‘no matches’ did not alert the user to her misunderstanding, so the interaction proceeds with the user believing her objective to be unachievable.

4.6 User E: Failure to Find AI in ACM Digital Library

The observation gave a striking example of a situation where the existence of multiple objectives caused interference between goals that the user was unaware of. The user was searching for articles related to artificial intelligence and HCI. She therefore entered ‘artificial intelligence human’ into the subject search box. However, she had previously been searching for authors with surname ‘Hollnagel’ – Hollnagel was still in the author search box. Therefore the user interface was set up to search for articles containing the words ‘artificial intelligence human’ and written by ‘Hollnagel’. Unsurprisingly, no articles are found.

The user’s attempt to reformulate the search did not improve matters. As illustrated in the follow excerpt, and in Figure 2, she reformulated the subject search box, but did not change the author search box:

```
[- ACM DL search page]
So even on full text.
Of course, its possible, no.
What happens if I turn off the human and
try again?
[> removes human from search terms]
[< subject search is now ‘artificial
intelligence’ (note – author search is
still ‘Hollnagel’)]
I would expect to get a fair amount.
[> clicks search]
[< search results replace search
formulation page – note no matches]
No matches. Ha ha ha.
```

Figure 2: Screenshot illustrating searching for both terms and authors

The information about the author search term was available on the screen, and in a short interaction the user would have remembered that the term had been entered. However, in this case, we see an extended interaction, with a transition to a different objective and the user's attention now focused on the subject information area of the screen. One analysis of this suggests that the entry of the author search term resulted in a latent error – in that it caused the user to subsequently issue an inappropriate search request. An alternative view says that the information about the search formulation is not being adequately communicated by the computer system to the user. Again, this is an example of an interactional trap – the user now believes to some extent that the library does not contain articles indexed by the terms 'artificial intelligence', even though it does.

4.7 User E: Failure to Find Recent IJHCS Issues in IDEAL

A further example comes when the user visits the IDEAL library and wants to look at the current issue of the IJHCS journal. The extract below shows part of the confusion the user suffers when she visits the current issue of IJHCS and finds that there are no articles displayed (see Figure 3)– confounding her expectation from her content familiarisation that the current issue's articles should be available. This confusion led to extended unproductive interaction and the user eventually giving up on the issue.

In the transcript below, attempts by the user to instigate events which are not actually part of the state potential are indicated by ❖. These illustrate how confused the user has become.

```
[> clicks on go (next to pop up menu
saying current issue)]
[< current issue page replaces journal
homepage (note - no contents)]
Shall I go to the current issue and have a
look what's there.
[pause]
Hmmmm.
[> clicks journal logo ❖]
[> clicks journal logo ❖]
[> clicks go button (next to pop up menu
saying list of issue)]
Where am I going?
[< list of journal issue replaces current
issue page]
OK. Errm.
[> clicks on most recent issue link]
[< current issue page replaces journal
homepage (note again – no contents)]
Err. What am I doing wrong?
[> clicks journal logo ❖]
[> clicks journal logo ❖]
[> clicks on pop-up navigation menu ❖]
[> clicks on IDEAL logo ❖]
```

Figure 3: Screenshot of IJHCS current issue page

The reason for the user being unable to access this journal issue was that the library had ceased to subscribe to IDEAL, so that only issues prior to a certain date could be accessed. This information was not available to the user.

Like the episode of interaction between user B and the ACM library, this interactional trap arose though the lack of mutuality at the outset of the interaction and the lack of opportunities for repair.

5 Conclusions

The Interactional traps discussed have features in common with each other, but also interesting differences. In focusing on traps, we have been concerned primarily with a *symptom* of interaction – that user and system lack mutual understanding such that the user acquires long-term incorrect beliefs about the achievability of their objective. Most of the interaction trajectories discussed take the general form:

$e_d > \ldots > e_n > e_{n+1} > e_{n+2} > e_{n+3} > e_{n+4} \ldots$

where e_d is the event at the point of deviation and e_n onwards are the events that result in the user acquiring the incorrect belief. In Reason's (1990) terms, e_d gives rise to a latent error. More specifically, e_d is a point at which mutuality is set at level 0 for a proposition that determines the achievability of the current objective. In other words, the agents are not even aware that they do not share common ground regarding an essential piece of information. This lack of awareness continues through the ensuing interaction: subsequent events do not result in repair of the error as normally happens in human–human conversation (e.g. Hirst *et al*, 1994).

For two of the interactions (sections 4.4 and 4.6), the deviation within the interaction was triggered by a high-level transition event; in section 4.4, this was due to the user unwittingly communicating with an agent (Science Direct) other than the one they were expecting; in section 4.6, the transition was in user objectives, which was not signalled adequately to the computer system.

For two of the interactions (sections 4.3 and 4.7), there is no point of deviation within the interaction, but a lack of common ground from the outset, together with a lack of repair.

At the *causes* level IF posits possible reasons for interactional trouble (in addition to drawing on external theories). In general terms, we have found that lack of mutuality is a central cause of interactional traps. In all cases, it was possible to identify a point of deviation, or to determine that mutuality was low from the outset. In addition, there were insufficient opportunities for repair. These are refinements of the general HCI mantra that the computer should give adequate feedback to minimise what Norman (1986) terms 'the gulf of execution'.

This analysis here been post-hoc, based on user data. Elsewhere (Bryan-Kinns et al, 2000) we have shown how the same ideas can be applied in a more predictive style to identify likely interactional traps at an earlier stage in implementation of a library.

Like most other web-based applications, digital libraries are subject to discretionary use, and therefore should be easy to 'walk up and use'. This study has highlighted the dangers of interactional traps within such interactions, and analysed them in terms of interaction trajectories and causes, with the aim of presenting more generalised understanding of causes, and hence of design alternatives that mitigate against such interactional difficulties.

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