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'Feature Interactions Outside Telecom Domain

Lynn Blair¹ Gordon Blair¹ Jianxiong Pang² Christof Efstratiou²

¹ Department of Computer Science Faculty of Science, University of Tromsø N-9037 Tromsø Norway.
Tel: +47 76 5209 Fax: +47 76 4480

² Computing Department Lancaster University Bailrigg Lancaster LA4 4YU, U.K.
Tel: +44(0)1524 593802 Fax: +44(0)1524 593608
email: {lgordon, efstrati}@comp.lancs.ac.uk pang@lancaster.ac.uk

Abstract. Feature interactions in the original sense of the term (i.e. within a telecommunications domain), have now been the subject of significant research activity for over ten years. This paper considers several different sources of interaction in the domain arising during the course of our research at Lancaster. These interactions are taken from a variety of areas within the field of Distributed Systems and stand to benefit greatly from the application of techniques developed in the feature interaction community. Furthermore, we believe they represent a potentially important generalisation of feature interaction research.

1 Introduction

The term *feature interaction* can simply be viewed as an “interference between services or features” [Calder00]; more specifically, such an interaction occurs when “the behaviour of one feature is affected by the behaviour of another feature or another instance of the same feature” [Kimble95]. Several taxonomies have been proposed in order to try and classify different types of interaction (including [Cameron94] [Kimble95] and [Hall98]). As simple, yet we believe helpful distinction from [Kimble95] is between:

- interactions that occur because the requirements of multiple features are not compatible and
- interactions that occur when a feature behaves differently in the presence of other features.

Within the telecommunications domain, there are numerous well-documented cases of feature interactions. For example, we refer here to the series of workshops in Feature Interactions in Telecommunications (and Software Systems), e.g. [Dini97], [Kimble98] and [Calder00]. However, recently it has become increasingly obvious that research into methods to detect and solve such interactions in telecommunications systems is also of great significance outside the telecom domain. In fact, as recognised in [Calder00], “the subject has relevance to any hardwired system where separate software entities control shared resources”. Furthermore, interactions can often be traced back to the fact that “two features manipulate the same entities in the base system and in doing so violate some underlying assumptions about these entities that the other features rely on” [Plath98].

In our earlier position paper [Blair00], we describe some interaction problems arising from Internet-based and multimedia/mobile systems that we describe in detail in the recently funded “FILBETT” project Feature Interactions: Life Beyond Tradition. This current paper extends our earlier one by providing new examples of interactions that

¹ Currently on leave from the Computing Department Lancaster University.

have arisen in research within the Distributed Multi University, in addition to cataloguing few other in the literature.

In the remainder of this paper, we first provide a brief project below (section 2) and then document some of what we have come across (section 3). Finally, we discuss some of the detection and resolution of feature interaction (section 5).

2 FILBETT: Life Beyond Traditional Telephony

2.1 Overview

Motivation for this project came from a number of examples we encountered when looking at Internet-based and multimedia services. As expressed by Heilmeier, "the telecom industry is quickly evolving from 'POTS' (plain old telephone services) to 'PANS' (pretty awesome new services)" [Heilmeier 98]. These new services are able to utilise the power of Internet-based (IP-based) and multimedia/mobilis systems and as the number of new services grows, the potential for interactions between services will inevitably explode.

The project addresses the main goal of the FILBETT project: to consider various new and emerging types of *feature interaction* that are likely to arise from the increasing popularity of *mobile* systems and services. A secondary, but still important, goal is to consider *IP-based* services and *multimedia* services. We plan to use formal modelling and analysis methods in this work, building on earlier work that we have done. Although the project is still in its early stages, some initial interaction examples are presented below.

2.2 Some non-traditional interaction scenarios

A number of interactions were identified in our previous position paper; these are listed below for detail the reader is referred to [Blair 00].

- combining traditional telecommunication services with Internet access
- potential interactions with one-to-many services
- TCP flow-control mechanisms and protocol interaction in general
- sharing demand on network bandwidth between browsing and viewing wide-area streams
- interactions occurring with multipoint conferencing units (MCUs)
- mobile resource interactions concerning bandwidth and power management
- problems with TCP over wireless networks

A number of further interactions have been identified in our work at Lancaster on mobile computing (see [Efstratiou 00] and [Efstratiou 01]). In a summary, most of these scenarios concern conflicting *adaptation policies*. In an attempt to maintain an appropriate level of quality of service, many mobile systems employ various adaptation mechanisms. However, if different adaptation mechanisms are employed for different attributes. Examples include mechanism to adapt/manage power consumption, network bandwidth proxy behaviour (e.g. in web browsing) and choice of location sensing mechanism. For example, consider a mobile device that employs two independent adaptation mechanisms: one for managing power and the other for managing network bandwidth. If power is running low, the power management mechanism will request applications that are

using network bandwidth to postpone this use, so as mode. However, as a consequence, the network adaptation unused bandwidth and will notify applications that direct conflict with the power management adaptation

to place the network device in sleep mechanism will now detect they can use this spare bandwidth, in mechanism!

Note that a further interesting dimension to adapt where by users can express preferences over different her *context*. For example, power management mechanisms may be crucial if the user is working in the field but less important in the office

ion is user-configuration of devices adaptation policies depending on his/her *context* where an alternative power supply exists.

3 Additional Interaction Scenarios

Whilst FILBET is primarily concerned with the generation of mobile, multimedia and P-based services, into such interactions does not stop there. Two further from the application of feature interaction research additional examples of ‘non-traditional’ interaction [Fireworks97] relating to email systems and variable system tape-deck system and network ticketing

alization of feature interaction scenarios is clear that the value of research areas from our work that would benefit are described below. As a side, some ns can be found in [Hall00] and ty of miscellaneous examples (including system etc.) respectively.

3.1 Component-based middleware

At Lancaster, we are interested in component-based middleware platforms such as the CORBA Component Model of CORBA v3, .NET or Enterprise Java Beans. Associated component-based development methodologies focus on the provision of means for specifying individual components together with their composition (i.e. an architecture) [Szyperki98]. By allowing new components to be added, and existing components, we obtain an incremental development model for evolutionary and dynamic architectures. However, this raises two key questions:

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- When we *compose* an architecture, how can we be confident that components will work well together that there are no unwanted subtle interactions and that the results are coherent?
- When we *adapt* an architecture, how can we be confident that replacement or updates behave as expected especially in tandem with other components?

Existing component-based methodologies provide little in the way of support for these problems. Typically, architectures are verified in terms of type compatibility between (required and provided) interfaces. In addition, checks may be carried out on the validity of architectures against certain style rules [Shaw96] [Medvidovic00]. However, this is not sufficient to capture the more subtle problems associated with unwanted interaction between components. This is an area that would benefit greatly from feature interaction research. In particular, a *design-time* check could be carried out on initial architectures and expected variations, whereas *run-time* techniques could be used to discover problems after re-configuration and also to catch problems unforeseen from static analysis.

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Adding an extra dimension to this analysis, we are also interested in *reflective middleware* whereby component-based approaches apply not only to the application/service level but also to the structure of the middleware itself [Blair98][Blair01]. Reflection is then used to provide introspection and adaptation of the middleware structure via a *meta-level*. This approach enables middleware to be customized for particular application domains, e.g. a small footprint system for an embedded device, and also to be re-configured if environmental assumptions change, e.g. to change a transport protocol or compression

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strategy for operating over a wireless link. Essentially this provides the extra capability of being able to adapt the non-functional properties of an application (real-time performance, security, availability etc). Again, it is vital to know if there are any unwanted side-effects of the changes, e.g. does the new availability policy conflict in any way with security requirements).

3.2 Behaviour in Co-operative Virtual Environments

PING is an EU-funded project looking at the development of an object-oriented framework for the support of distributed and co-operative virtual environments, which can then be specialised on a per-application basis (IST-1999-11488) Lancaster University is responsible, along with others, with the modelling of behaviour in such virtual environments. The approach is to represent all entities in virtual environments as passive or active objects. A passively exposed attribute that can be altered through interaction with other objects; an active object on the other hand also includes behaviour (which in Ping is expressed as a series of reactive scripts written in the Junior scripting language [Boussinot01]). We are investigating an aspect-oriented approach to composing such behaviours using Junior, with consideration of any aspects including the capturing of (virtual) world physics (gravity, inertia etc) distributed systems policies such as replication and consistency management, reaction to collisions and autonomous behaviour relating to the object. Furthermore, it is important in PING to be able to adapt behaviour as environmental conditions change, e.g. to minimise dissemination of information foraging and adaptation will be modelled as further behavioural aspects, resulting in self-adapting object behaviours (c.f. reflection above).

Although this is a rather different application domain considered above. In particular, we are concerned about the initial configuration and the subsequent re-configuration of a platform. In this case however, we are concerned about interaction between behaviours at both an inter- and intra-object level. Importantly, in this work we already have a significant advantage in that Junior has a formal operational semantics (expressed using rewriting rules) [Boussinot00] thus aiding formal analysis.

4 A Brief Summary of Feature Interaction Detection and Resolution Techniques

Existing analysis techniques can be seen to fall into two broad categories: *off-line* (or design-time) techniques, *on-line* (or run-time) techniques and *hybrid* techniques [Calder99].

4.1 Off-line Techniques

With *off-line* techniques, a model of the base system and the additional services or features are specified in a formal language whilst the properties that the system should exhibit are (typically) specified through a set of temporal logic Axioms and modelling languages (FSMs), LOTOS, Petri-Nets, Promela and SDL. However, as the number of service groups grows, there is clearly an issue of the scalability of such techniques and tools. Importantly, though, major improvements have been forthcoming in model-checking techniques recently for example through the use of on-the-fly and symbolic techniques and also the use of abstraction and symmetry. Such techniques are a problem. A further problem however is that the development of successful techniques is dependent on the accuracy of the specified properties. An inaccurate or rather non-precise or no-lead to missed interactions (as occurred in [Bousquin01] a priori knowledge of the behaviour of the individual services and features.

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become increasingly (dynamically) adaptive. Adaptation is powered by a knowledge database, such as predefined data types and user agent rules. For example, in [Griffiths94] unknown new features are accommodated through a 'adaptive agent regime' architecture where an agent engages in negotiation to settle the discerned conflict between

features. Strategies have typically been tables, state transition rules, abstract

Finally, in recognition of the advantages (and certain limitations) of a hybrid approach is proposed in [Calder99]. This approach is a resolution of interactions between new services and legacy services and combines a non-line, transactional approach with off-line formal analysis (see also [Marple00]).

drawbacks) both off-line and on-line. This approach is a resolution of interactions between new services and legacy services and combines a non-line, transactional approach with off-line formal analysis (see also [Marple00]).

5 Conclusions

It should be apparent from the discussions above that there are many benefits from results in the field of feature interaction where we believe this to be the case including mobile-based and reflective middleware and also behavioural

many areas of computer science can be identified. We have identified a number of areas and multimedia systems, component-specific interaction in virtual environments.

An interesting first line of research is to consider interaction problems including for example the potential (required/provided interfaces) [Szyperski98]. More generally, further research is clearly required to bring the different research communities, in order to more fully understand the relationships between feature interaction and these other areas.

the impact of components on the feature interaction. Explicit context dependencies simplify analysis of potential interactions, including strong collaboration between fully understand the relationships

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at Lancaster which have contributed. In particular, we would like to thank into mobile computing, the various component-based and reflective interactions in virtual environments.

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