Requirements Engineering in the Long-Term: Fifty Years of Telephony Feature Evolution

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Abstract: Systems are useful to the extent that the potential benefit they provide customers outweigh the responsibility costs that customers incur to realize those benefits. We develop a classification of benefits (potentials) and costs (responsibilities) in the domain of interpersonal communication features. Using this classification, we chart the introduction and availability of telephony features to private telephone subscribers over a fifty-year period in a metropolitan area. The growth of features occurred in bursts, emphasized different potentials over time, and they imposed burdens on customers that increased with the power of the features themselves. A punctuated equilibrium model of evolution explains discontinuities in the introduction of features, the displacement of some older features by newer ones, and the dynamics of the cost/benefit tradeoffs that subscribers experience. We explain the non-uniform introduction of types of feature over time in terms of the cultural and technological evolution of telephony use. In particular, we identify three expansion epochs in which the major concerns were communication, privacy, and accessibility and awareness. We show how the implications of the then incumbent requirements engineering in the context of long-lived, feature-rich multi-agent systems.

I. INTRODUCTION

Requirements engineering principles and practices are designed to assure the appropriateness of system features. In situations where the costs of making a wrong decision exceed the costs of making a right decision, system designers and engineers cannot assess the appropriateness of proposed features by simply asking customers what they want [Bec98, Pot95a]. Since such systems tend to be E-type systems [Leh80, LBB85] that continue evolving to adapt to changes in their environment, new features always appear in the context of existing features, modes of use, enabling technologies, and architectural patterns.

Features are complex systems of required and assumed behaviors. The cohesiveness of these behaviors determines the feature fit into and shapes its environment and how it interacts with other features or ways of working. An understanding of how features evolve would therefore benefit requirements planners and system architects. Some authors also suggest that services appear directly in the implementation architecture as application-layer subsystems [Ben97], a strategy that could provide an avenue for requirements-based system composition and aggregation.

Whether a feature is appropriate is a complex judgment. and the trade-offs among benefits and costs, we adopt an equilibrium model in which features are useful to the extent that the benefits they provide customers outweigh the responsibility costs that customers incur to realize those benefits. Customers, as in the usage of the Soft Systems Methodology [CS90], are intended beneficiaries of a feature, whether they are paying customers, end users, or indirect beneficiaries. Benefits of a feature are any potential capabilities that the customer may achieve, while responsibilities of a feature are the mitigating behaviors and properties. Features logically cohere over time in terms of the cultural and technological context of telephony use. In particular, we identify three expansion epochs in which the major concerns were communication, privacy, and accessibility and awareness. We show how the implications of the then incumbent requirements engineering in the context of long-lived, feature-rich multi-agent systems.

A. Features and Other Modeling Constructs

Features are closely related to other concepts, such as goals, architecture components, use cases, scenarios, observations, and vocabulary.

1) Goals and the purposefulness of features

A feature involves the choreographed actions of several agents, all of whom are agents because the feature promotes the achievement of one of the beneficiary’s goals. We judge as appropriate those features that support goals. For example, “call waiting” avoids missing calls (or, more abstractly, maintaining contact even when away from one’s usual location). Those features that do not support goals or that support minor goals are deemed unnecessary. Features tend to be needlessly complex and pointless or merely decorative. While the agents and actions of a feature are relatively unambiguous and objectively determined, its purposes are more fluid and subjective. Customers, requirements engineers and inventors predict poorly the value of proposed features, since customer goals often unclear and volatile. Indeed, a new feature may create further demands because of accidental affordances; as in the use of answering machines to screen calls.

Previous research in requirements engineering has developed a rich theory of goals and their refinement into system constraints and operations [Am96, Am98, vLD95], the obstacles that may block goals in the deployed system’s environment [Bec98, Pot95a], and the potential requirements engineering in the context of long-lived, feature-rich multi-agent systems.

2) Features, use cases and scenarios

Use cases are closely related to use cases [Jac92, Fow97]. Use cases are models of system use that external agents initiate with a purposeful input. Although authors in the object-oriented methodology invented the concept of use cases [Jac92], use cases are less object-oriented than scenarios. Since the telephony system is clearly modularizing requirements into logically coherent bundles, we can analyze by considering the emergence of features in existing systems. Since required features are simply hoped-for propositions, we can analyze by considering the emergence of features in existing systems. Since required features are simply hoped-for propositions, we can analyze by considering the emergence of features in existing systems. Since required features are simply hoped-for propositions, we can analyze by considering the emergence of features in existing systems.
different person from the subscriber) initiates an identification episode, a type of episode that is repeated for every subsequent incoming call (Note that the identification need not be successful for the episode to occur.). Other features may involve more types of episode. For example, voicemail involves subscriber identification and recording a message; retrieving messages, and even, arguably, replying to them. A use-case analysis of Caller ID Deluxe would differ markedly in its treatment of the subscription and calling episodes completely different use cases. Indeed, recent accounts of use-case analysis re-cast use cases themselves as a type of “actor” outside the system with which the use case interacts [Sch98]. Here, for example, the call use case would interact with the subscription use case in exactly the same sense that it interacts with the recipient. This awkwardness in reifying subordinate use cases arises from regarding use cases as tools for suggesting object classes and designing physical components from them. The longer-term purposefulness and coherence of the episodes, so important to the customer, becomes fragmented from the architectural perspective. Requirements engineering benefits from an initial use cases, but they benefit in turn from a semantics that connects them to purpose, call activities [Pot95b, Pot99].

One agent always initiates each phase or episode of a feature scenario. The initiation of an episode may be the accidental by-product of the initiator pursuing other goals. For example, a customer may place a call to view their Caller ID, and then realize that they wanted to call a friend. Other initiations occur when the customer deliberately initiates the calling and identification episode, because the caller’s goal is merely to communicate with the recipient. The identification goal is a goal of the recipient, not the caller.

3) Involvement of subsystems in feature provision

Features always involve some automated actions in the system, and may also elucidate interactions among subsystems. In requirements engineering from the Context Diagrams of Structural Analysis [DeM97] to the formal specification of operational examples, written and practitioners traditionally regard the required system as a single black-box. More recently, attention has turned to the evolution of systems whose major parts are not fixed [Goc97, Pot99]. Whether a feature requires the recognition of internal system components depends on whose perspective is being adopted. The native telephone subscriber, for example, may not distinguish between the switch or network database subsystems and the billing system, but may acknowledge a difference between the local switch and the caller’s in the case of a long-distance call. In earlier times, subscribers had to adopt different behaviors when calling a local call, a “really” local call, a long-distance call to some cities, and a long-distance Mediation. Even the booking and use of the system in these cases inevitably involves some decomposition into distributed components.

Emerging things like incorporation of an external entity or the automation of previously external behaviors, and in these cases it is more useful to preserve the knowledge of the physical division of responsibilities, espoused by, for example, many strong and users enabled to adopt workaround procedures. Specific examples of multi-component responsibilities are those that the system implements in parallel. Examples include the ability to look up and activities that are initiated by request. In telephone, they were initially provided by human operators, but sometimes now involve fully automated services that nevertheless seem separate from the core services that they mediate. For example, many features require subscribers to call a special number to activate or access a service. The number acts as an automated operator and often accesses a service with which the caller interacts through speech and dialing actions.

4) Features, obstacles and breakdowns

A feature provides a customer with the potential to achieve goals, but this potential may remain fallow for many reasons. Equipment failures or system unavailability may prevent the feature from being unavailable, or degraded. Unwillingness or inability to perform an associated action, such as looking at a display panel or discriminating among several dial tones that encode information about the incoming call also undermines the value of the feature. These are obstacles [Pot95b, Pot99].

Features are not the only ways for a customer to achieve his or her goals. Workarounds are bundles of manual behaviors and the inventive uses of other automated features to achieve the same purpose, albeit often imperfectly and less conveniently. In the absence of Caller ID, a caller and recipient might agree on a code that identifies the caller, such as ringing twice in quick succession. Workarounds may be useful in the presence of feature unavailability (e.g. excessive cost, or temporary breakdown), but they typically result in degraded outcomes and require additional responsibility, including, sometimes additional actions by agents that are not intended.

What starts as a workaround may later become partly automated and “colonize” the niche of an existing feature in the customer’s space of goals. Conversely, workarounds may disappear. For example, many strong and users enabled to adopt workaround procedures. Specific examples of multi-component responsibilities are those that the system implements in parallel. Examples include the ability to look up and activities that are initiated by request. In telephone, they were initially provided by human operators, but sometimes now involve fully automated services that nevertheless seem separate from the core services that they mediate. For example, many features require subscribers to call a special number to activate or access a service. The number acts as an automated operator and often accesses a service with which the caller interacts through speech and dialing actions.

1) The Positive Side: Potential

Potential refers to the goals that customers can achieve with a feature that they could not achieve or could achieve less adequately in its absence. Features provide types of goal-achieving potential in two categories as follows:

- Communication: Being able to communicate information with other people beyond the potential afforded by the system’s infrastructure. For example, in telemarketing, Three Way Calling allows customers to communicate simultaneously with two parties and the picture phone enhances the basic level of communication via additional receipt of visual information.

- Privacy: Being free from interception, being less likely to disclose personal information or being more autonomous in communication decisions. For example, Anonymous Call Rejection offers both freedom from interception and privacy since subscribers will not be disturbed when a caller with Line Blocking calls.

2) The Negative Side: Burden

The growth of features and potentials imposed burdens on customers that increased along with the power of the features themselves; we characterize these burdens as follows:

- Equipment: The need for purchasing or providing specialized equipment to enable a feature. With the advent of Caller ID, special Caller ID boxes and telephones with built-in Caller ID support became available.

- Setup: Special actions needed to initiate availability of the service but not normally required operationally. These include subscription actions, programming of short cuts, etc.

- Cognitive: Additional cognitive load, including short-term memory, discrimination of coded signals and decisions to act. In the case of RingMaster, subscribers must distinguish among three distinctive ring patterns that signify the recipient. Call Waiting requires subscribers to decide whether they are available.

3) Degree of automation

Customers experience different degrees of automation among features. We classify features require some form of external intervention; for example, the assistance of a telephone operator in order to obtain the desired potential of a feature. Modality characteristics of these different kinds. A feature can be made between the types of mediation; mediated features may involve more types of episode. For example, Speed Calling maximizes cognitive resources by allowing subscribers to reach frequently called numbers by dialing only one digit.
automated mediation occurs when subscribers dial a Special Access Number (SAN) to experience the benefit of a feature (e.g., voice mail and remote call forwarding). Those features that do not require the assistance of an operator or the dialing of a SAN are non-mediated.

C. Feature Evolution

Feature evolution is the phenomenon by which a system’s features change over time as the subscriber’s experience suggests that the dominant form of feature evolution is the addition of new features to a baseline, but existing features may become refined or specialized. However, such a model is rudimentary because gradually accumulating features explain the continued growth of non-mediated features. For example, Caller ID Deluxe, which provides both the name and number of the person calling the subscriber, was introduced in 1967 (the first of the consecutive years for which we have more detailed data). While the subscriber’s experience suggests that the call’s phone number. We examined the growth of telephony features over a period of 51 years (1948-1999) in a major metropolitan area. Feature growth occurred in bursts, as shown in Figure 3, and we characterize these bursts as periods of feature expansion.

Figure 3: Telephony Features Per Year (1948-1999)

Figure 3 portrays a punctuated (non-continuous) feature growth, marked by four major feature expansions: Year 5 (1971), Year 14 (1980), Year 23 (1989) and Years 28-29 (1994-95). These four periods of expansion were each introduced during emerging technological innovations. While the expansion of 1971 is not due to the new availability of a particular enabling technology, it is significant because it marks the first clear introduction of a cluster of features. Touch-tone service was introduced in 1980 and it spurred the second major expansion during which Speed Calling and Three Way Calling were introduced.

Another distinction between features remains to be made. We distinguish between baseline, new, and displaced features as follows. A set of new features introduced before and during an expansion is referred to as a feature cohort and the set of features that are removed before the next expansion is a displacement cohort. The features that comprise each expansion's feature baseline, feature cohort, and displacement cohort are listed in Table 1. The introduction of features and the displacement of older features by new features are visible.

<table>
<thead>
<tr>
<th>Expansion</th>
<th>Baseline</th>
<th>Feature Cohort</th>
<th>Displacement Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>Beep Tone, TwoParty</td>
<td>Collect Conf Calls P2P</td>
<td>none</td>
</tr>
<tr>
<td>1980</td>
<td>Beep Tone, Collect Conf Calls P2P, TwoParty</td>
<td>BillTo3rd CallFwd CallWait PicPhone SpeedCall TDD TimeCharges ThreeWay TTY</td>
<td>BeepTone PicPhone TDD TwoParty</td>
</tr>
<tr>
<td>1989</td>
<td>BillTo3rd CallFwd CallWait Collect ConfCalls P2P SpeedCall TimeCharges ThreeWay TTY</td>
<td>CallBlock CallReturn CallSelector CallTracing PrefCallFwd RepeatDial RestrctCallCard SeqCalling TDD R111</td>
<td>RestrctCallCard SequenceCall TDD TTY 911</td>
</tr>
<tr>
<td>1994-95</td>
<td>BillTo3rd CallBlock CallFwd CallWait CallReturn CallSelect CallTracing Collect ConfCalls P2P SpeedCall TimeCharges ThreeWay TTY</td>
<td>Block900 CallBlock1dListing CallDar2hnt CallFwdAll CallFwdBusy CallFwdDontAns CallFwdMain RemoteCallFwd Ringmaster TTY</td>
<td>BillTo3rd CallBlock900 CallDar2hnt CallFwdAll CallFwdMain ConfCalls P2P</td>
</tr>
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Figure 4: Degree of Automation in Feature Baseline

Table 1: Feature Expansion

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<th>Major Expansion Periods</th>
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<tr>
<td>Humans-Mediated</td>
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Although one would expect the degree of automation to increase over time, it is interesting to note that this trend was actually slowed or even reversed by the introduction of newer, powerful features that require occasional mediation. As shown in Figure 4, the number of non-mediated features has risen dramatically since 1980. While the number of automated mediation features only began to rise during the last expansion period, the number of human mediated features is clearly declining. Perhaps this is due, in part, to the fact that many new systems initially require a staff of specially trained users or professionalize some aspects of system use. Later, however, automation tends to decentralize this expertise (disintermediation) and return responsibility to the user as evidenced by the continued growth of non-mediated features. Each feature expansion has allowed customers to become more dependent on the system since they are now more able to control what they do when they employ these services without having to rely on other agents to achieve their goals.

There is some evidence that potential declines immediately after an expansion. A diffusion explanation of this is that technological opportunities make many “near” features possible, which are subsequently consolidated when it turns out that they are not all necessary or are contested on regulatory grounds. An evolutionary explanation is that some previous features are now seen to be redundant and the new ones displace them, as in the displacement of Caller ID by Caller ID Deluxe. Each new feature is supported by some degree of automation as discussed below.

D. Degree of Automation

During the early years of Plain Old Telephone Service (POTS), most specific features required long distance service or voicemail to the customer to subscribe to the service. In contrast, placing a call collect still requires an operator, who then places the call. Table 1 distinguishes such mediated features from non-mediated features by displaying the mediated features in italics. In Figure 4, features are charted according to their degrees of automation (non-mediated as well as human and automated mediation).
Telephony has certainly come a long way from the late 1800's when there was uncertainty as to whether customers would be able to succeed at such cognitively complex tasks as dialing a simple phone number!

D. Telephony Feature Potential

Figure 5 charts the feature potential for each of these five categories. We observed that total potential rose in accordance with software-evolutionary theory which enabled customers to more readily achieve their goals; thus, it stands to reason that each individual potential category experienced a corresponding increase in potential, although several individual trends and three years are particularly noteworthy: Year 13 (1980), Year 22 (1989) and Year 28 (1995). In 1980, four features were introduced (Three way Calling, Call Forwarding, Call Waiting and Speed Calling) which significantly increased communication potential by providing more effective ways of getting in touch with one another. The growth in communication potential that year is attributed to the introduction of these features. A sharp increase in the potential for privacy is also illustrated in Figure 5. This is partly due to the inception of a growing concern for privacy in 1989 with the introduction of features such as Call Block, Call Selector and Call Tracing. These new features afforded customers the potential to better manage their presence and ensure that unwanted interruptions would be limited or minimized. In 1995, all five categories of potential experienced an expansion. This "across the board" increase in potential characterized a number of more broad spanning features which touched all five kinds of potential.

Feature expansions have been driven by a desire for more effective and convenient modes of communication, we expect this trend towards increased potential to continue, but with each increment systems come an increase in burden or responsibility on the part of the customer or subscriber as discussed below.

E. Telephony Feature Burden

Figure 6 charts the five kinds of feature burden per year. According to Bell Southern, the only known modern widespread releases of OS-360, during which changes were locally optimized. Cost and reliability per unit change re-stabilized when the architecture was redesigned every few years. The growing entropy of local changes is countered by periodic global effort. In biology, too, major speciation events have been explained in terms of the diversity-rewarding effects of major and geologically sudden climatic changes. Such changes, jolts from the outside, encourage rapid diffusion into newly created niches. Punctuated change is also observed in the history of science [Fau97, Spe95].

Our classification scheme arose out of earlier work in goal-directed requirements engineering [Ant96, Ant99] and the general theory of value. Nevertheless, a more general scheme would be beneficial in applying our results in other domains. Our classification scheme arose using the practices of grounded theory [Gla67]. We think it is important not to invent or propose a universal taxonomy of benefit types for all types of system, but instead to use one's knowledge of a broad domain, including knowledge gained during data collection itself, to shape such a classification scheme. Our goal, after all, is to provide practical help to requirements engineering, not to develop a general theory of value. Nevertheless, a more general scheme would be beneficial in applying our results in other domains.

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