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Controversy Corner

The discourse on tool integration beyond technology, a literature survey ☆

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ABSTRACT

The tool integration research area emerged in the 1980s. This survey focuses on those strands of tool integration research that discuss issues beyond technology.

We reveal a discourse centered around six frequently mentioned non-functional properties. These properties have been discussed in relation to technology and high level issues. However, while technical details have been covered, high level issues and, by extension, the contexts in which tool integration can be found, are treated indifferently. We conclude that this indifference needs to be challenged, and research on a larger set of stakeholders and contexts initiated.

An inventory of the use of classification schemes underlines the difficulty of evolving the classical classification scheme published by Wasserman. Two frequently mentioned redefinitions are highlighted to facilitate their wider use.

A closer look at the limited number of research methods and the poor attention to research design indicates a need for a changed set of research methods. We propose more *critical* case studies and method diversification through theory triangulation.

Additionally, among disparate discourses we highlight several focusing on standardization which are likely to contain relevant findings. This suggests that open communities employed in the context of (pre-)standardization could be especially important in furthering the targeted discourse.

1. Introduction

Tool integration is a cross-disciplinary research area incorporating influences from many fields, such as *Software Engineering, Systems Engineering, Human-Machine Interaction* and *Economics*. Buxton's STONEMAN report is often mentioned as a starting point for the discussion on tool integration (Buxton, 1980). Buxton (1980) specified the requirements for a *support environment* for programming Ada by defining the appropriate tools, tool integration mechanisms and interfaces, but also introduced the notion of integrating tools throughout a software project life-cycle. During the 1980s a plethora of initiatives to specify support environments followed, the most well known being the European Portable Common Tool Environment (PCTE) initiative. In the late 1980s and early 1990s, this carried over into an intense academic discussion regarding many different types of support environments. It was already clear at this point that the research on tool integration consisted of several different strands of research (Brown, 1993a). The identified strands currently include the (overlapping) categories of tool integration versus mechanisms, technology, frameworks, semantics, modelling, process, dimensions, types, standards and industrial experience (Brown, 1993a; Maalej, 2009; Wicks, 2004). Throughout the last two decades, the strand that has seen the majority of the activity is the one that focuses on the *technology*, i.e. the separate mechanisms for achieving tool integration (Wicks and Dewar, 2007). Many valuable findings and insightful discussions are found in this particular strand of research, for instance those related to technological innovations such as Eclipse and Open Services for Lifecycle Collaboration (OSLC). The former is an innovative plug-in framework technology that once turned the entire tool integration market upside down, while the latter is a web API technology that currently shows promise of a large impact. However, the other strands of work are also important, although their influence is currently much more difficult to appraise.

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This paper focuses on those strands of tool integration research *that have implications beyond a specific technology*. It contributes to the body of knowledge in tool integration by providing an exploratory literature survey focused on the issues with (and discussion of) tool integration that go beyond solving technological challenges. Our hope is that this will support disruptive change. Incremental changes to technology are valuable, but progress in the tool integration field has been painstakingly slow. If the solutions provided by academia cannot gain traction and impact within industry, then our understanding of industry must be flawed. Identifying missing knowledge might eventually facilitate more relevant technological choices. It could also lead to the removal of unknown, non-technological obstacles hindering the successful deployment of tool integration. Furthermore, it should point to changes to current research approaches to allow for more efficient, conclusive research into the field.

The background is our part in the iFEST project (iFEST Consortium, 2013), an EU research project focusing on the specification and implementation of an integration framework for establishing and maintaining tool chains to engineer complex industrial embedded systems. While building support environments is a challenging task due to the sheer complexity of todays technology, many of the difficulties encountered during iFEST were not linked to technology *per se*. The choice of a particular approach or technology could make perfect sense to one stakeholder, while another discounted it outright. The ensuing discussions pointed at a lack of adequate research into more high level questions, such as how to prioritize between business models, stakeholders or even different academic discourses.

To avoid a situation in which discussions would have degenerated into a mere battle of wills, and to enable an unbiased approach to tool integration, we chose early on to focus on the strands of research that try to reach an *overall* understanding of what tool integration *is*. Thus, by identifying the essential core of the cross-disciplinary discourse related to tool integration, we aimed to facilitate future decisions on tradeoffs and identify any weaknesses in the discourse that may make such decisions difficult. To achieve this, we designed a literature survey that focused on what we called the *essence of tool integration* – how it is discussed, the context of this discussion and what the implications are. In other words, the survey focused on the non-technical aspects of the tool integration literature, such as how tool integration is defined, if the concept can be further divided into separate parts, what its purpose is and what is required to achieve it. In addition, the survey considered when these types of questions tended to arise and to what purpose. This also means that we have tried to go beyond discussing such things as individual meta-models, reference models and patterns, at least beyond what is motivated by our approach. While these capture important aspects of tool integration at an abstract level, they focus on functionality and usually do not cover the even higher levels of abstraction targeted by this study.

The basis for the paper is, as will be explained in the subsequent sections, a paper by Wasserman (1990). This paper is a widely recognized seminal paper in the strands of research focusing on issues of tool integration beyond technology. The status of this paper stems from its definition of what later became a much used classification scheme based on different "dimensions" of tool integration, namely *Control, Data, Platform, Presentation* and *Process Integration*. It has been popular to use these dimensions as support when reasoning about tool integration. This scheme is further described in Section 5.

The paper is divided into five distinct parts due to the exploratory nature of the study. The first part defines the questions that guided our exploratory investigation (Section 1) and motivates the approach toward answering these questions (Section 2). The second part discusses how these questions led to the allocation of the surveyed papers into initial categories based on common traits or unique contributions related to the initial questions (Section 3). In the third part these categories are used to elicit and analyze four ways in which the discussion of tool integration that go beyond solving technological challenges is either strong or weak (separate discussions in Sections 4–7). Which conclusions that are possible to draw based on these analyses is discussed in the fourth part of the paper (Sections 8). Finally, the core findings and conclusions are summarized in the last part (Section 9).

2. An iterative literature survey

This section starts with explaining the approach of this literature survey. A case is then made for the validity of the research findings based on the approach and extra precautions taken.

2.1. The approach

The findings presented in this paper come from an iterative literature survey, which took place over a period of 4 years.

The first iteration, in which the *State of the Art* of tool integration was studied, took place early 2010 during the start of the iFEST project. The 39 sources studied during this iteration consisted of most[1] of the *Association for Computing Machinery* (ACM) Digital Library (Association for Computing Machinery, 2013) database citation list for Wasserman (1990).

The second iteration took place between 2010 and 2012, at the same time as the main part of the iFEST project. Made up of a consortium of 21 partners, consisting of international companies and universities, much input was obtained on different approaches to tool integration. When compiling the most interesting work obtained in regard to the essence of tool integration, it became obvious that most of these sources were based on or oriented around Wasserman (1990).

The third iteration took part from late 2012 to early 2013 and focused on the sources in the ACM Digital Library (Association for Computing Machinery, 2013) and the Google Scholar (Google, 2013) databases which cite Wasserman (1990). All highly cited sources[2] from 1990 to early 2013 were included. Furthermore, *all* sources issued from 2007 to 2012 were included in the study regardless of how many times they had been cited. These criteria ensured that all relevant sources received from iFEST partners during the previous iteration were formally included. At this time a total of 75 relevant sources had been identified during the second and third iteration.[3] Based on the discussion in these sources, a further 15 sources of interest were identified, bringing the total number surveyed during the second and third iteration up to 90. In practice this primarily involved using citations to backtrack to sources discussing classification schemes other than Wasserman's.

In the final iteration the whole set of sources were surveyed again to summarize and double-check the data presented in this paper. Out of 129 sources, 117 were eventually used as a basis for the survey. The 12 sources excluded were deemed not to contribute to the targeted discussion, i.e. the discussion of what we called the *essence of tool integration*. This decision was based on a careful reading of the complete sources after which we could not include them in any of the categories described in Section 3. This does not reflect on the quality of these sources or their usefulness in surveys with other focuses.

2.2. The validity of the findings

There is much advice to be found on how to conduct a literature survey, but time must be spent on *research design* to ensure the

[1] One source was not possible to obtain.

[2] A high count was defined as 20 citations or more.

[3] In comparison with the first iteration, the citation lists contained 90 additional sources fitting the criteria at this time. However, 1 source did actually not refer to Wasserman (1990), 7 sources could not be used due to language difficulties and 7 sources proved to be inaccessible. Only 4 of the excluded sources were from the highly cited category.