# Towards a Novel Issue Tracking System for "Industry 4.0" Environments

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## Abstract
In this paper we describe the concept and system design of a novel tracking system for deviations and disturbances in a production environment. We motivate the need for such a system by reporting our observations of two production systems of German manufacturing companies. Our envisioned system focuses on helping and motivating people to digitally document the problems, potential causes and steps to overcome the issues more thoroughly and provide capabilities that make these easily accessible at the point in time when they are needed. Such a functionality is not only helpful for problem solving in the general production system itself, but can also be used for other specific aspects of it, e.g. errors requiring documentation in the manual end-assembly that can also profit from the same strategies.

## Author Keywords
Issue tracking; CSCW; Industry 4.0; Digitalization

## ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

## Introduction
Industry is on the threshold of the fourth industrial revolution [6]. Prospective industrial production will be,

Issue tracking systems are well known in the area of software development and IT support, i.e. bug tracking systems such as JIRA or help desk applications such as Spiceworks. Even more tools are available, with a large variety of different functions. Currently, there are also several platforms that encourage people to find bugs on other web pages or mobile applications and post these bugs in tickets on their webpage ("Crowdtesting"). These companies pay per bug, which serves as a motivator, but on top of that they also use other strategies to ensure that the documentation quality becomes reasonably good for their customers (as they often put these bugs directly into their own bug tracking facilities), e.g. gamification elements or supervised revisions. For our purposes it seems unclear which set of features is really necessary to motivate people and encourage them to document the issues properly. One goal of our research agenda is to contribute an understanding of which seem necessary in industrial settings.

**Text box 1:** Issue tracking in practice

among other aspects, highly adaptive to account for the creation of individual products. Reconfigurations of the production environment will be the standard, not the exception. To reduce the complexity in such manufacturing systems, employees, will be supported with assistance applications (e.g. [7]). The tracking of deviations and disturbances in production systems is already a relevant topic nowadays, but is going to become even more important in such highly adaptive environments. Depending on the system design, applications that help people pinpoint possible causes and solutions are also useful in environments not yet following the "Industry 4.0" vision.

In this paper, we introduce the idea of an issue tracking system for such industrial settings with the goal of motivating employees to create a more thorough documentation of problems and solutions and make that information easily accessible when needed. As a precondition we need to move from analogous settings (which seemed still to be available nowadays as we will outline after the related work section), in which issues are documented on paper to a digital counterpart in which we can deploy persuasive and motivational strategies on top of the other advantages such a digital system provides. The documentation itself serves as a formalization of the expert knowledge, currently only bound to specific employees and makes it accessible even when these experts are temporarily or permanently absent. Besides the obvious advantage that past problems can then more easily be targeted in the future, such systems might also help to provide a good basis for new employees. Based on our findings, we describe a first prototype design. With it, we have a testbed for persuasive and motivational strategies to investigate which combination seemed to work best in this domain.

## Related Work

From a scientific point of view (complementary see also Text box 1) in [3] an overview of problem solving tools in the production domain is given together with hints when to use which tool. Issue tracking itself is often investigated in context of bug tracking tools. An examination of them [1] shows that current systems suffer from information overload that is possibly remedied by personalized views. To what extent this issue is also relevant in manufacturing is not yet clear, but introducing issue tools outside of software engineering seems promising. For example, in [10] issue tracking was introduced in clinical research and improved quality of data. MacDuffie illustrates how complex problem solving in the context of manufacturing is and that much depends on the experience of the people involved [8]. Hence, an approach that makes this expert knowledge available seems reasonable. According to Bertram et al. [2], in a collocated team the issue tracking system becomes a fundamental communication tool and knowledge repository, although quality and comprehensiveness of documentation suffers from differing viewpoints on the issue described and hence leads to incomplete knowledge bases. So far, we have not found approaches that investigate the improvement of such documentation by employing persuasive methods.

## Two Industrial Views

During the initial requirement elicitation in two large German manufacturing companies (cf. Text box 2), we discussed with the stakeholders and potential users how an digital issue tracking system making use of persuasive technologies could help them in their daily work. We also elicited whether they have a need for such improvements. We want to note that these findings are not necessarily generalizable, but nevertheless illustrate the case at hand.

**Company 1 (C1), 37.500 employees**: Study focus on general production system

*Methods*: Multiple focus group discussions over several months with varying group sizes (2-5) and user groups (but all would later be users of the system) and unstructured interviews with various stakeholders.

*Topics*: Status quo, how a digital counterpart could help, process analysis, issues with current approach, are persuasive methods necessary?

**Company 2 (C2), 800 employees**: Study focus on end-assembly process

*Methods*: Multiple group discussions with 3-5 stakeholders.

*Topics*: Presentation of results of company 1, status quo, narrowing down the focus on end-assembly and repair documentation, are persuasive methods necessary?

**Text box 2:** Overview of methods and topics

In our elicitation process, we learned that deviations in C1 needed to be documented first by taking hand-written notes on a list only accessible in a specific place. In this area, all information relevant for the corresponding assembly line is collected which is part of their continuous improvement process (CIP [5]). Not everyone is allowed to fill out this list, and they are required to verbally report to an authorized person. The core information that needs to be written down is: who created the note, when it happened and to which area or process it belongs. Besides such administrative information, of more importance are the description of the deviation or disturbance, the potential cause (after analyzing the issue) and which measures were taken to solve the problem. There are complementary processes (which are also documented) that give a structure to find the proper cause and solution of problems (e.g. Six Sigma [3]). In theory, such information seems valuable for later occurrences of the same error, especially if the person involved in the solution process of the first instance is unavailable. We also learned that not only an improved general issue tracking for C2 might be helpful, but specific instances, such as improved repairman's documentation of erroneously-assembled products, could benefit parts of the production system, in this case the manual end-assembly, for proper worker feedback. We learned that there are several problems with the current approaches in both companies:

- The documentation is often too imprecise to aid during reoccurrences. Reasons might be that people do not see any real advantage in documentation, that they do not know how to do it better, or that they are simply not motivated to document properly. Motivational features are seen as necessary for improvements. We also learned that errors are made in this process (e.g. mixing up columns).
- The document itself is potentially only available at a fixed location and space for the different information items is limited.
- Former documented cases are not easily accessible when they are needed. After the document page is full, it will be archived in a way that is not yet electronically accessible. In the case of C2, there is no direct connection between systems that would profit from such a connection directly.
- It is hard to track which steps for solving the issue were unsuccessful. Only the final solution is documented. We lose this kind of information, which might be useful for other instances.
- During the problem solving process much information is shared either verbally or by email and is not accessible for other people later on.
- Whether certain solutions were really helpful on a long-term basis is also not obvious as there is no definite workflow to review this for every solution.

*Lessons learned*

Besides obvious improvements such as mobile availability of the to-be-digitalized documentation, it is clear that an improved issue tracking system should also support the user by finding related earlier documented occurrences while interacting with our system or entering a new problem. Most importantly though, we learned that the current documentation style is often not useful. In consequence, even if a system could suggest earlier occurrences, the information might not be sufficient to be of any help in the current situation. Thus, the integration of motivational and persuasive elements could facilitate more thorough documentation and it seems reasonable to implement some kind of review to ensure a proper documentation quality before something is considered to be suggested later on.

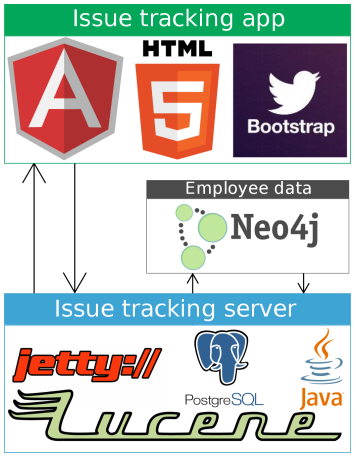


**Figure 1:** Overview of used libraries and components. HTML 5 and Twitter Bootstrap is used for the front end, AngularJS as model-view-controller framework and Java for the server (with corresponding tools). Communication is realized with WebSockets and a RESTful API. We use PostgreSQL as main ticket system database and Neo4j, a graph database, to handle data associated with the overall production system (as this seems reasonable in "Industry 4.0" settings, cf. [7]); in our case employee data.

## Concept and System Design

Based on the lessons learned, we created a "ticket system" prototype, to overcome the identified problems by providing a structured way of entering problems and solutions, integrating options to ensure a certain quality of these tickets, giving suggestions to related, former tickets and providing motivational elements for ticket creators. It is usable in non-"Industry 4.0" settings, but we will also outline, what can be gained if such a setting is available. This prototype will be used in further sessions with the users in the companies later on, to understand the design space of issue tracking in the industrial domain.

*Overall design*

To ensure that our tickets can be accessed across devices, we implemented a web app (see Figure 1 for an overview). From a functional view, we needed to ensure that the problems are documented in a structured, easy way. For this, based on the information which is currently collected on paper, we allow for entering short titles, a description of the issue (cf. Figure 2), causes and measures taken. For the latter two, it can be noted that the cause was, for example, not correct, or that the measures did not work. We will thereby not lose information possibly relevant later or can also use this information for continuous improvement processes [5]. We also allow uploads of additional multimedia content (e.g. videos). Speech-to-text is offered for users averse to typing, but ticket modification is synchronized across devices to allow an easy transition from one device to the other.

*Social components*

We encourage collaborative work on tickets, as problems in the industrial setting often involve more departments. For this, we also make use of social media features that should facilitate not only the work on a ticket, but also

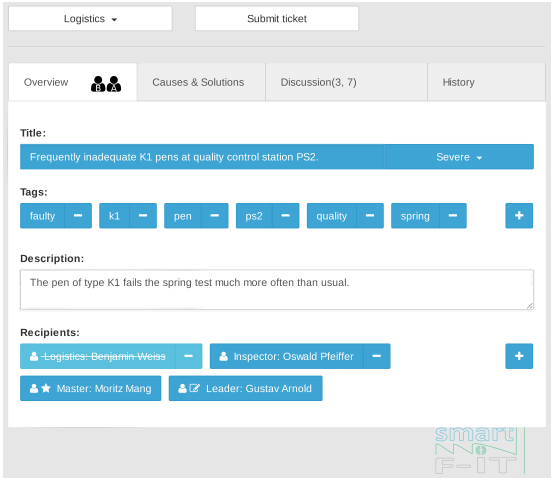


**Figure 2:** Ticket detail view.

help in the process of finding proper causes and solutions. We allow the creator of a ticket to add further collaborators to it. They will immediately be informed about their new involvement by an in-app and e-mail notification. Now, they can (similarly to a GoogleDoc) edit every field collaboratively and will see which other collaborators are currently working on this ticket. They also can see if a certain collaborator is currently not available for participation (e.g. because he is sick). In addition, they can discuss the ticket on a meta level through a StackExchange-like discussion time line for each ticket. When a specific number of contributors think that the ticket is addressed, it can be sent to a supervisor. He or she will check whether the documentation quality is adequate and only then also consider whether the solution was really effective (e.g. by also considering monitoring data). If either is not the case, the supervisor reopens the ticket and provides feedback. The contributors are informed about this and need to improve the ticket or find

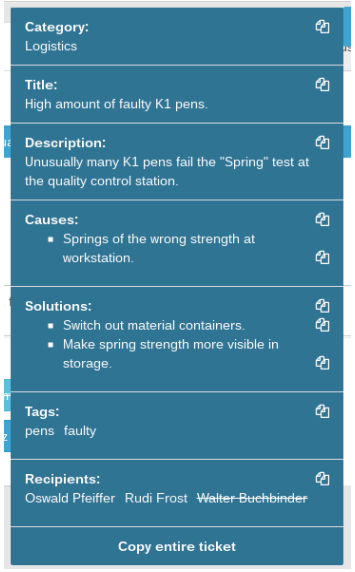


**Figure 3:** Example of a previous ticket suggestion. This ticket would be retrieved if the information as shown in Figure 2 were entered in a new ticket.

another solution. An apparently effective solution might turn out to be only a short-term solution. To account for this the supervisor needs to set a date for review at which the effectiveness of the chosen solution will be reevaluated. In this state he or she will enhance the ticket with the information on whether or not the measure was still effective, after which the ticket can be completed.

*Historical considerations*

To create our knowledge base, we index every ticket which was accepted by the supervisor in terms of short-term effectiveness and documentation quality with Lucene[1]. To make this knowledge base more searchable, we let the ticket users also add tags to the ticket, and they can categorize it (e.g. technical, logistics, etc.). Users of our issue tracking system will have three options to gain access to such older tickets (or parts of them). First, they can actively search for phrases and receive tickets in the order of relevance. Second, while entering input into specific fields in a ticket, we suggest related entries of this field from older tickets. Third, the newly entered ticket will be compared to tickets in the knowledge base and while filling out the different aspects of the new ticket, the collaborators will always see how many other tickets are related, have the chance to inspect them and can partially or completely adopt them (cf. Figure 3). Here, one can also have the chance to assign the ticket to the employees who were formerly involved in the process. From a more recent point of view, the collaborators can also inspect every change in a new ticket in a local history.

*Persuasive/motivational components*

Besides the digitizing of the issue tracking process, it is also important to encourage people to document their work more thoroughly, as this was revealed to be problematic currently. We utilized persuasive strategies (the terms used are explained in [9]) to potentially fulfill this goal: First, by providing functions that help employees to find the cause of a deviation and give them knowledge to overcome it quickly, by structured entering of problems and by suggesting former tickets (*Reduction, Suggestion*), we demonstrate what can be gained by using our system properly (*Expertise*). Second, the collaborative functions lessen the burden on a single individual, and involving other people also establishes a potential feeling of teamwork (*Collaboration, Social facilitation*). Finally, the check by a superior puts *Social Pressure* on the ticket users. There are strategies we envision for the system, but they are not integrated in the prototype yet: namely, gamification (*Rewards, Competition, Social Comparison*), as it seems to work well in the aforementioned crowdtesting scenario; *Self-monitoring*, to show users how much they have contributed; and *Personalization* and *Tailoring* to better handle the large amount of information. Which of these strategies works best in this domain will be investigated with the prototype.

*"Industry 4.0"-extensions*

The prototype as it is described can further profit from the "Industry 4.0" vision. Most relevant will be the detection of states in the production system. As one goal is, that the virtual model always mirrors the real world, it becomes possible [4] to use the virtual state as fingerprint to find and suggest earlier tickets that have a similar fingerprint – even without receiving any information from the users first, and potentially before the issue becomes imminent for employees. Another extension, currently already available in the prototype by using structures explained in [7], is the coupling with specific aspects of this virtual model, such as employee data and hierarchies. This can be used to find specific supervisors who need to be

[1] http://lucene.apache.org [accessed: 2015-07-02]

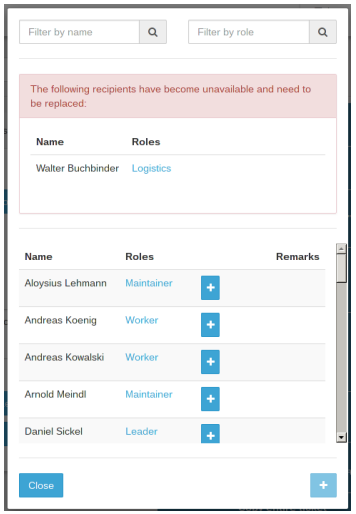


**Figure 4:** Adding a collaborator with the same function, as the system recognizes that the person who participated in the old ticket is not available anymore.

informed about the ticket automatically or to always keep the information on employees updated, e.g. when they are currently or permanently absent. We are also able to derive which person has the same function in the company as the one who is unavailable (but related to a former ticket) and can directly suggest alternatives (cf. Figure 4).

## Discussion and Next Steps

We plan a two-step evaluation of the prototype in terms of its perceived usefulness and complexity. The first step will be a focus group discussion on it. After adapting the most relevant aspects we will then monitor the usage of the system in the manufacturing environments of both companies over multiple weeks with several feedback loops. Besides obvious deeper insights into the acceptance and usage patterns, we will also have a test bed for persuasive strategies in this context. As a positive side effect (and precondition for the measurement of a persuasive effect), we can thereby acquire tickets which we can analyze in terms of word count and usefulness, but can also improve the search capabilities, if necessary. This research agenda will help to understand which capabilities issue tracking systems need to have in this domain.

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