Towards responsible software engineering: combining value-based processes, agile practices, and green metering

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***Abstract*—In contemporary software engineering, business value and end user requirements are the primary drivers for design decisions. Ethical values such as fairness and sustainability, a key concern in green software engineering, are complementary, non-technical drivers addressed by value-based systems engineering as, for instance, specified in IEEE Standard 7000. Such process-centric initiatives explain what should be done but not how to get there. Practitioners are assumed to be able and willing to locate documents such as codes of conduct; document study is required ("pull"). A proactive, lightweight integration into existing agile practices, providing tangible on-the-job advice for developers and other stakeholders, is missing ("push"). Our research agenda addresses this problem area. Following a proactive approach, we propose to combine existing work to ease access to and consumption of ethical and green design knowledge for a world in which software systems are increasingly no longer passive tools for users but make autonomous decisions affecting human lives and the planet. In this short paper, we report on a completed and two emerging projects in this topic area in terms of their goals, preliminary results, and envisioned future work.**

***Keywords*—design ethics, value-based systems engineering, method engineering, sustainability, green software engineering**

I. Introduction

Stakeholders of software and software development projects are diverse. They have wants and needs, face practical constraints, and fall for cognitive biases. Numerous ethical values that can be promoted or harmed exist; sustainability is a particularly important one. Such values often remain tacit; conflicts among them and other requirements may arise. Value-based engineering methods [1], [2] help to make values explicit and to prioritize them. They yield a new breed of system requirements to be addressed in the software design work, decision making and architecture modeling in particular.

Design and code reviews provide opportunities to check for conformance with/satisfaction of value requirements such as sustainability. Tools such as compilers, linters, or static code analyzers may report maintainability smells such as circular or risky external dependencies; however, such tools are unable to report an excessive carbon footprint of generated code, violations of fairness policies, or other moral obligations.

In this short paper, we report results from a completed project and introduce two emerging ones tackling this topic area w.r.t. their goals, preliminary results, ongoing work, and research opportunities. The topic concerns the entire society, as everybody is exposed to software in some way nowadays. Our work specifically targets socially responsible software engineers who see the risk that the software under construction may have undesired, unexpected, and/or unjustified effects on one or more of its stakeholder groups and want to manage and mitigate the risks caused by these effects. We use the term "software engineer" broadly to include roles like requirements engineer, architect, developer, tester, operator, and maintainer.

The remainder of this paper is structured in the following way: Section II presents related work. Section III outlines our research vision and features three projects with their goals, approaches, preliminary results, and directions. Section IV summarizes and provides an outlook on future work.

II. Related Work

The IEEE Standard 7000-2021, "Standard Model Process for Addressing Ethical Concerns during System Design", which we refer to as IEEE Std. 7000 from now on, defines five analysis and design processes; it also suggests – but does not norm – an initial catalog of core values. IEEE Std. 7000 "aims to support organizations in creating ethical value through system design. Creating ethical value is a vision for organizations that recognizes their central role in society as shapers of well-being and carriers of societal progress that benefits humanity. Implementing IEEE Std. 7000 can help them to strengthen their value proposition and avoid value harms. It applies to all kinds of products and services." [3]

Gotterbarn and Rogerson proposed "Responsible Risk Assessment with Software Development: Creating the Software Development Impact Statement" (SoDIS) [4] and Proactive CARE [5]. Their work is based on Codes of Conduct such as the ACM one [6]. Value-Sensitive Design (VSD), introduced

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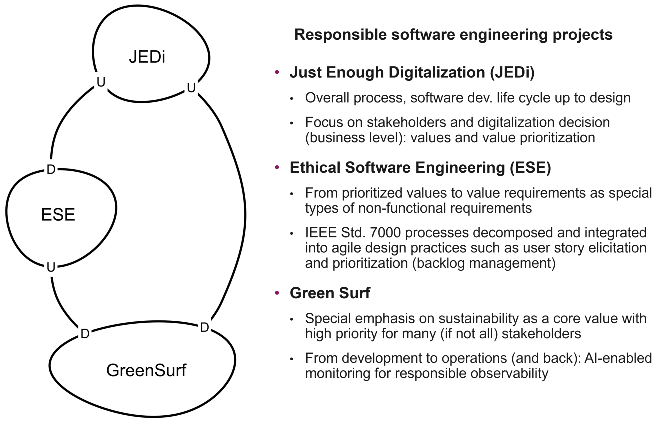

Responsible software engineering projects

- **Just Enough Digitalization (JEDi)**
  - Overall process, software dev. life cycle up to design
  - Focus on stakeholders and digitalization decision (business level): values and value prioritization
- **Ethical Software Engineering (ESE)**
  - From prioritized values to value requirements as special types of non-functional requirements
  - IEEE Std. 7000 processes decomposed and integrated into agile design practices such as user story elicitation and prioritization (backlog management)
- **Green Surf**
  - Special emphasis on sustainability as a core value with high priority for many (if not all) stakeholders
  - From development to operations (and back): AI-enabled monitoring for responsible observability

Fig. 1. Projects and their (U)pstream-(D)ownstream dependency relations

by Friedman and Hendry [7], is a theoretically grounded approach to technology design that accounts for human values. Winkler et al. [8] conducted a review of methodological practices in VSD projects. Spiekermann introduces Value-Based Engineering (VBE) [9].

Human values and sustainability are closely intertwined: Values guide our actions and decisions and influence how we interact with the environment. Winkler proposes "Human Values as the Basis for Sustainable Software Development" [10] to not only focus on technical but also social and environmental sustainability. Software can promote sustainability by optimizing resource use and increasing consumer awareness [11], but its design and use affect its environmental impact.

III. Our Research Vision and Projects

Our research vision and mission statement is:

We aim at enabling responsible software engineers, users of software-intensive systems, and their other stakeholders to make conscious and informed decisions that consider positive and negative impacts on ethical values, such as sustainability, explicitly when developing, operating, using, and maintaining such systems.

Figure 1 gives an overview of the three projects presented in this paper. A DDD context map shows how they relate to each other. On these projects, we apply and extend general-purpose software engineering methods such as Attribute-Driven Design (ADD) and Domain-Driven Design (DDD), as we already have done for our Design Practice Reference (DPR) [12]. These choices are in line with recent trends in practice; the adoption of DDD is growing. Quality orientation, as emphasized in ADD, has been a core tenet in the software architecture community since its beginnings [13].

A. JEDi: Just Enough Digitalization

Context and problem. Digitalized solutions attempt to support and/or automate all kinds of business processes, make work easier for human beings, and fulfill economic goals. While economic values receive a lot of attention, it is often forgotten that digitalizing our world "wherever we can" potentially has negative impacts on human values as well. Digital solutions do not necessarily make the world a better place – or their influence on our society is not only positive. For example, while many online services such as social networks or video streaming services may connect and entertain us, there is a risk of "keeping us hooked" and promoting addictive behavior; the absence of *face-to-face* communication might make people feel lonely. Engineers sometimes seem to forget to consider the perspectives of everyone involved with and affected by a new software solution.

Solution. To improve the situation, the recently started ***Just Enough Digitalization (JEDi)*** project proposes to examine all perspectives and uncover conflicts, leading to a discourse that brings out satisfactory solutions for everyone and avoids (or at least minimizes) harm to any human being. If negative impacts predominate positive ones, a system should maybe not be built at all. Therefore, different people with different positions should communicate before deciding whether a system should be developed or not. JEDi aims to stimulate such discussions and increase awareness that human and ethical values should be key concerns in digitalization decisions.

JEDi proposes a process called *Value-Driven Analysis and Design* (VDAD) consisting of seven steps: 1) Acquire Domain Understanding, 2) Identify Stakeholders, 3) Identify Values per Stakeholder, 4) Prioritize Stakeholder Values, 5) Make Digitalization Decision, 6) Derive New and Adjust Existing Requirements, 7) Design Software Architecture.

Domain-driven approaches already focus on human communication, and DDD practitioners, therefore, seem to be a promising community to raise critical questions and stimulate critical thinking regarding digitalization. All steps above aim at applying domain-driven, collaborative practices such as Domain Modelling, Event Storming, Domain Storytelling, and Impact Mapping. We refer the reader to [14] for more information about the VDAD steps and these practices.

The VDAD process aims to involve all stakeholder values in the software development process. An important step of the proposed process is, therefore, the identification of stakeholders. A stakeholder map such as the one in Figure 2, helps to identify and visualize stakeholders directly or indirectly impacted by a system. Once all stakeholders have been identified, their values shall be modeled and then serve as input for other artifacts, e.g., functional and non-functional requirements, architecture design, and the running software.

We hope that our JEDi project will lead to improvements towards digital transformations from which all human beings and our society can benefit. Systems that potentially harm human and ethical values shall either not be built at all – or at least improved in a way so that harm to society is minimized. Knowing all stakeholders and their values is paramount for making better digitalization decisions.

B. ESE: IEEE Std. 7000 meets agile practices

We completed a first project called ***Ethical Software Engineering (ESE)*** [15] that focuses on JEDi steps 3 to 6.

Problem. ESE investigated three research questions:

1. How can ethical awareness be stimulated and integrated

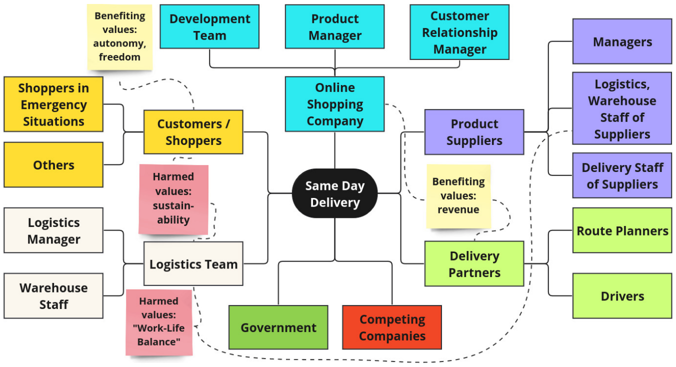
Benefiting values: autonomy, freedom
Development Team
Product Manager
Customer Relationship Manager
Managers
Shoppers in Emergency Situations
Customers / Shoppers
Online Shopping Company
Product Suppliers
Logistics, Warehouse Staff of Suppliers
Others
Harmed values: sustain-ability
Same Day Delivery
Benefiting values: revenue
Delivery Staff of Suppliers
Logistics Manager
Route Planners
Delivery Partners
Logistics Team
Warehouse Staff
Harmed values: "Work-Life Balance"
Drivers
Government
Competing Companies

Fig. 2. JEDi: Value-Driven Analysis and Design Process – Exemplary Stakeholder Map for an Online Shop Scenario

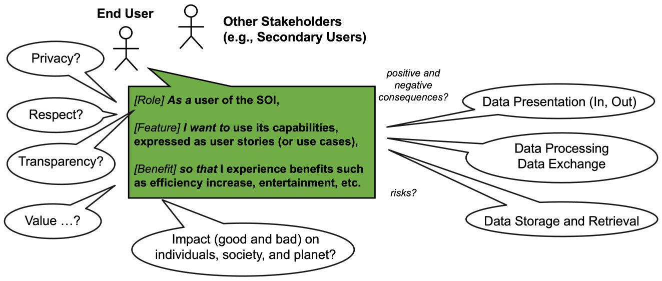
End User
Other Stakeholders (e.g., Secondary Users)
Privacy?
Respect?
Transparency?
Value ...?
[Role] As a user of the SOI,
[Feature] I want to use its capabilities, expressed as user stories (or use cases),
[Benefit] so that I experience benefits such as efficiency increase, entertainment, etc.
positive and negative consequences?
risks?
Data Presentation (In, Out)
Data Processing Data Exchange
Data Storage and Retrieval
Impact (good and bad) on individuals, society, and planet?

Fig. 3. User Story-Driven Value Elicitation in ESE: Role-Feature-Benefit Structure Analysis (SOI: System of Interest)

into agile software practices?
2. How can ethical concerns be actively identified and weighted against other requirements?
3. How can methods and tools trigger, assist, and validate ethical behavior on agile projects?
Solution. ESE delivered a set of practices that answer the above questions. These "as-light-as-possible" practices aim to increase the chances of agile projects and product development efforts becoming compliant with IEEE Std. 7000.

ESE includes a total of nine agile practices: 1) Story Valuation activity, 2) Ethical Review activity and artifact, 3) extended Definition of Done, 4) extended Definition of Ready, 5) Value Retrospective, 6) Acceptance Testing, 7) Product Backlog, 8) Sprint Planning, and 9) User Story [16].

ESE practices 1) to 5) are novel or extend existing ones; the other ones remain unchanged. *Story Valuation* is the entry point for ESE usage. We provide usage instructions, suggest notations, and list techniques to perform the activity in a public method repository [15]. The repository specifies input and output, covers notation in depth, describes the techniques in detail, and provides examples and pointers to the literature. We only highlight a few selected method elements here.

Instructions. The practice description in ESE Release 1.0 advises to: "Add individual, societal, and environmental values to the business and user values in the "so that" part of epics, user stories, or other types of product backlog items. Do so from the perspective of different stakeholder groups; compare and prioritize their value clusters and derive value requirements from them. Start this activity in Product Vision (or Sprint 0 or Minimum Viable Product development); return to it and resume valuation in each sprint/iteration as/if needed. Apply one of the techniques in ESE to do so and record your results in one of the proposed notations; alternatively, work with your own (or other recognized) techniques and notations. ESE is suggestive and not normative in this regard."

Techniques. The valuation techniques proposed by ESE are a) *Goals and Vision First*: Question-Based Elicitation, b) *User Requirements First*: Story-Driven Value Jam, see Figure 3, and c) *Individual Values First*: Catalog-Guided Value Mapping.

Notations. ESE does not *mandate* a certain format for the IEEE Std. 7000 Value Register [3]; overview figures and comparison tables can be well suited. However, ESE still *suggests* three novel register formats: Value Epic, Value Weighting, and Value Narrative; the ESE repository provides templates and examples for them. Ethical Value Requirements (EVRs), for instance, may take this form: "As a [role], I want to [action/feature] so that [benefit] is achieved and that [values a, b, c] are promoted, accepting that [values x, y, z] are reduced." The first three clauses ("As-a", "I want to", "so that") form a well-established template in the Agile community specifying role, feature, and benefit of the story; the new clauses "and that" and "accepting that" add positive and negative value impact and other ethical consequences of an implementation of the feature described by the story.

In conclusion, the ESE vision is to combine lean agile practices and IEEE Std. 7000 for their mutual benefit in terms of breadth and depth in a best-of-both-worlds approach – which is challenging but important and worth trying.

C. Green Surf: carbon footprint modeling, simulation, and smart metering of Web applications

Sustainability is one of the core values of IEEE Std. 7000 [3], which is picked up by ESE and its Story Valuation practice. Our third project targets this value, specifically environmental sustainability (JEDi step 7) and onwards).
Context. Digitalization, and thus software, is a transformative force that is becoming increasingly important in all areas of our lives; applying JEDi step 7, we propose ***Green Surf*** to support footprint modeling, simulation, and metering of Web application components and infrastructure.

The application and integration of Artificial Intelligence (AI) will continue or even accelerate this trend. While this offers fascinating possibilities, we should not lose sight of the hidden costs that come with it. Developing, operating, and using digital services is consuming an increasing part of our world in terms of energy and other resource usage and the resulting pollution. A study by Freitag et al. [17] estimates that the global emissions of the Information Communication Technology (ICT) sector could already be as high as 3.9%. In a recently published technical report by the European Commission, the authors estimate that "the combined energy use of data centres and telecommunication networks in the EU was [...] equivalent to 2.8–3.8% of total regional electricity use", with data centers in Ireland accounting for 18% of the total national electricity usage [18].

The adoption of AI is still in its infancy, but considering the massive higher energy consumption compared to "traditional" applications, the ICT sector's share of energy usage will likely grow. For example, there seems to be a trend for search engines to have AI-generated answers augmenting search results [19]. An interaction with a Large Language Model (LLM) could require as much as ten times the energy of a regular keyword search [20]. Responsible software engineers must consider the environmental impact before using AI everywhere.

Problem. One problem we see is that users of digital services are unaware of the resource consumption (not just energy but also water) and associated emissions their usage causes. Resource consumption and emissions are not noticeable for users, as they occur in the data centers and during power generation; this stands in contrast to other waste. E.g., plastic packaging accumulates in the household bin; verbose HTTP requests and responses message bodies do not. Telecommunication networks and data centers account for around two-thirds of the carbon footprint of ICT [17]. From a household perspective, the energy required to charge a smartphone is negligible compared to heating or cooking [21].

Solution. We plan to explore how to display resource consumption and emissions at the point of origin in terms of time ("real-time pollution") and space (in the living room, so to speak) and to make it specifically measurable and traceable – a "smart meter" for digital resources. Various indicators (displays/visualizations) are conceivable, e.g., a digital twin of the earth that shows when very large amounts of data are transmitted via the Internet in the household or a plant that starts to wilt and decay when a daily emission budget is exceeded. It would also be possible to show consumption compared to other citizens and thus stimulate a change; technical measures would also be conceivable, e.g., a limit on bandwidth or even automatic CO_2 compensation payments.

Our vision here is to raise users' awareness of the impact of their online activities, thus empowering and motivating them to change to more responsible behavior.

IV. Summary and Outlook

In this paper, we outlined our research vision for responsible software engineering and gave an overview of a completed, an ongoing, and a proposed project. We target software engineers wishing to create ethically valuable, sustainable software and to make responsible digitalization decisions.

Our emerging methods JEDi and ESE aim to balance human values, such as fairness and diversity, with agile values, such as customer collaboration and responding to change. The third research project on green web surfing stands at an early stage; we expect it to benefit from our previous work in the other projects and the green software engineering research community. We make our results openly available. For instance, the ESE method is openly available on GitHub [22]. We welcome feedback; the ESE method repository provides an experimentation folder that presents a validation task.

Open issues and opportunities for future work include scaling value elicitation up, managing goal-value conflicts effectively, as well as detecting green and ethics washing.

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