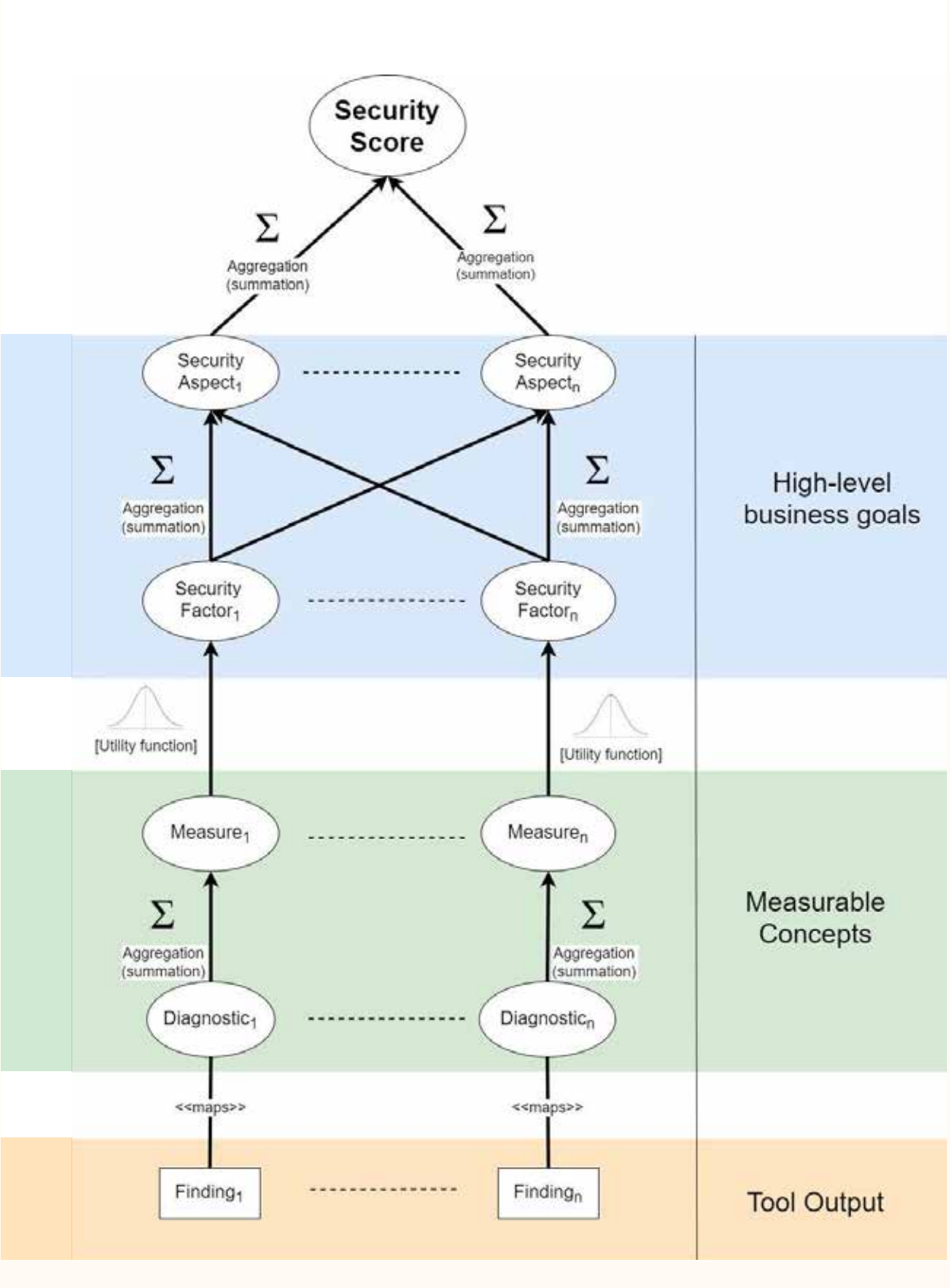
A Generalized approach to the operationalization of Software Quality Models

RESEARCH QUESTION:

Can we develop an extensible, flexible, and independent framework for operationalizing software quality across various domains, while enabling modelers to independently select their tools?



INTRODUCTION

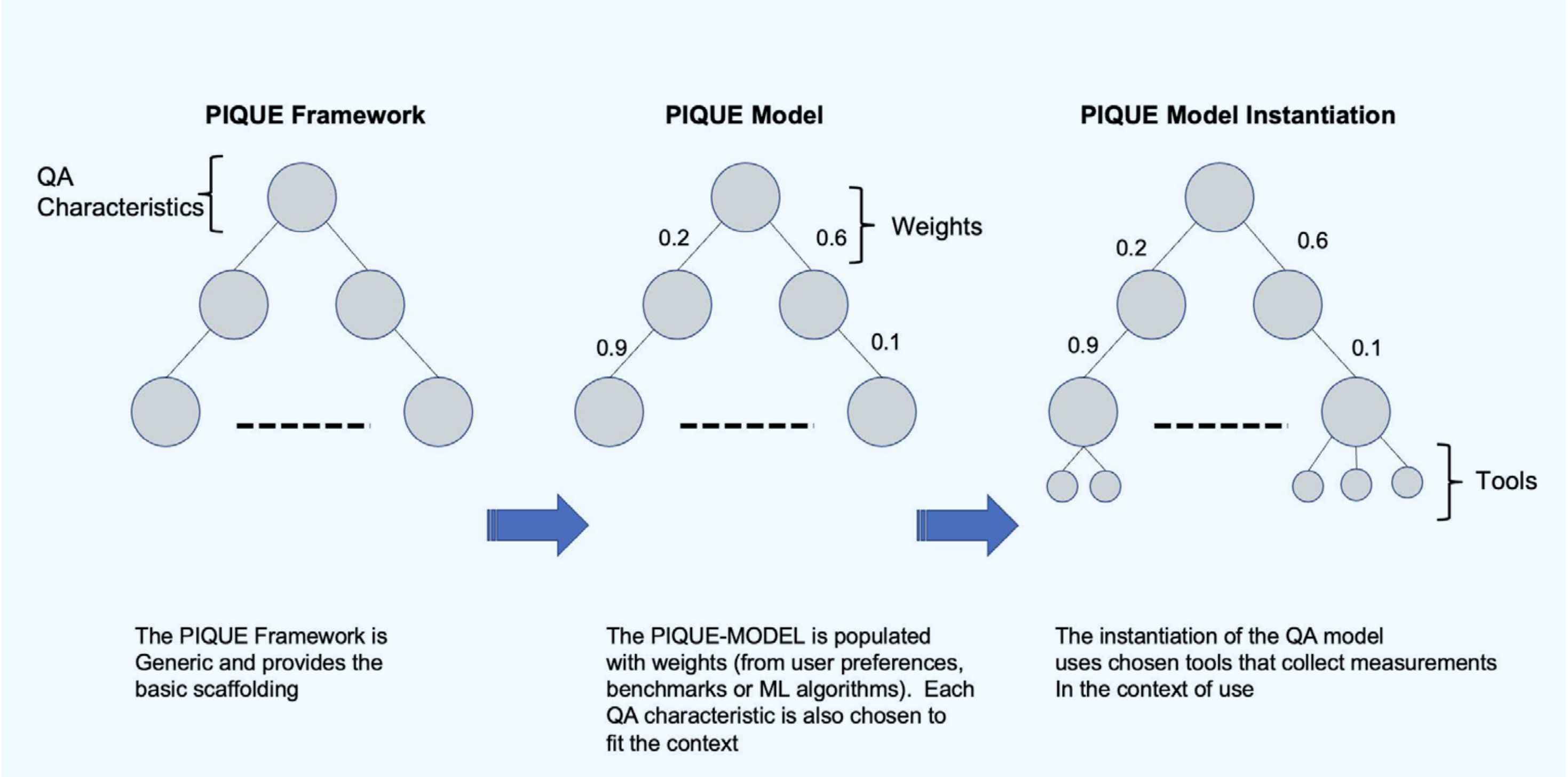
Capturing the notion of quality is a wicked problem (Rittel and Webber (1973)) because of the inherent variability from multiple sources such as tools, tool versions, and measurement scales. Further, the subjectivity of a quality score is influenced by the mechanisms associated with the weighting of characteristics against each other, the lack of appropriate domain-specific benchmarks that can be used to calibrate scores, and the selection of tools that can act as proxies for theoretical characteristics (e.g., ISO models).

Deficiencies in software quality cause billions of dollars in losses and degrade organizational reputation. To address these deficiencies, we have developed a framework that implements Hierarchical Software Quality Assurance (HSQA)— PIQUE. PIQUE is effective because it provides a systematic approach for identifying deficiencies in software quality—including crucial characteristics such as cybersecurity. By identifying these deficiencies with PIQUE, developers can make necessary adjustments to ensure best practices are fully implemented—such as modifiability-by-design and security-by-design. These best practices are critical for securing the software supply chain and protecting our digital systems across industry, government, and military sectors. These digital systems incorporate numerous, large, and complex software projects—projects that cannot afford to fail. By providing a means for the thorough evaluation, PIQUE catches defects early to prevent weaknesses in code from becoming crises.

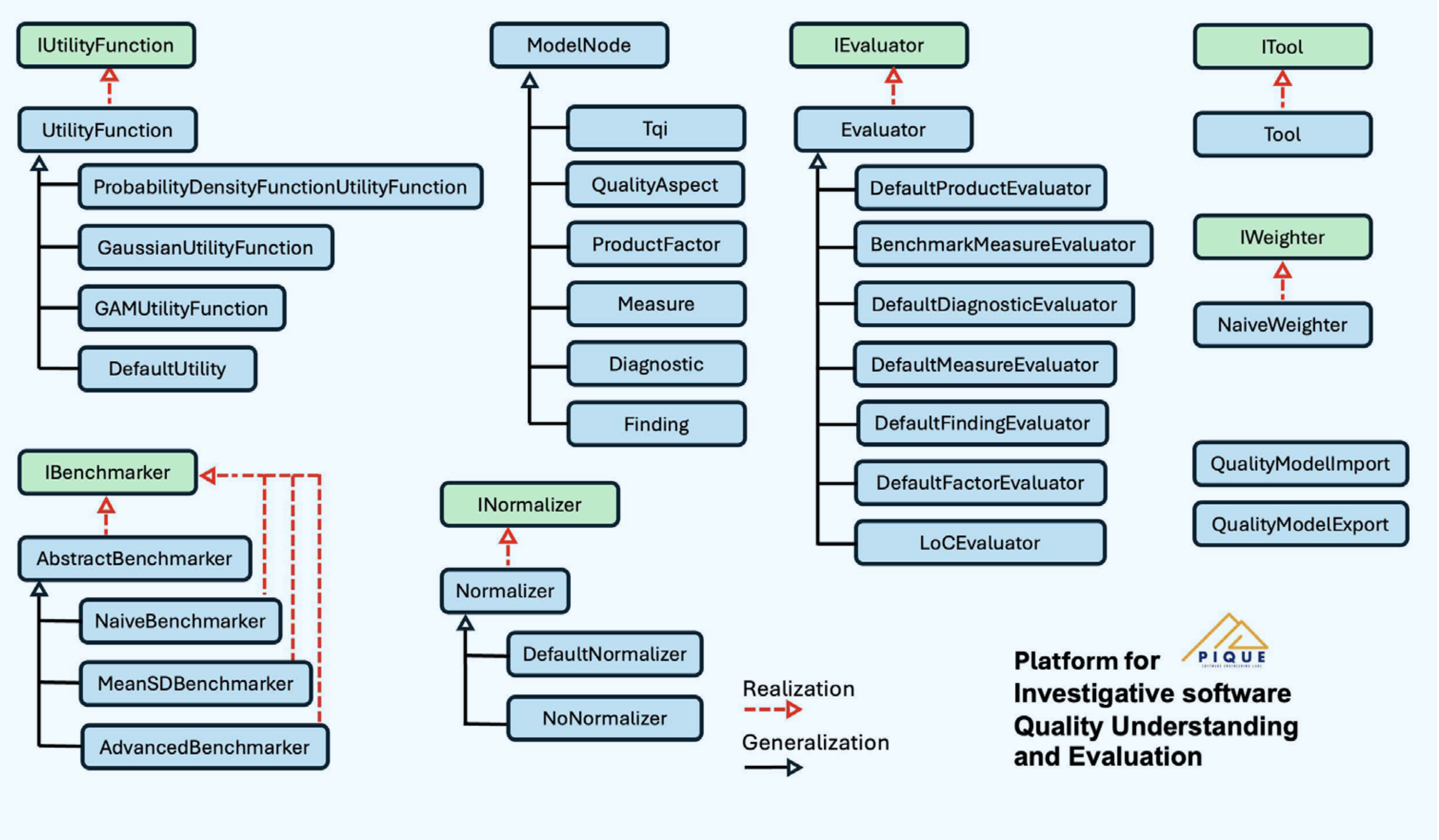
THE PIQUE FRAMEWORK

Specifically, we deliver the following contributions with the PIQUE framework:

1. We extend the capabilities of prior art by specifying a new meta-model that allows for the operationalization of agnostic quality models that can be tailored to use any underlying standards such as ISO, STRIDE, CWE families.
2. We have developed improvements in aggregation techniques, benchmarking and utility function mapping. We have also improved on manual weighing approaches between layers of a hierarchical model by employing ML techniques that are trained on exemplary data.
3. We allow developers to integrate new tools, and leverage existing tools that can connect to PIQUE models.
4. We provide visualization technology that addresses concerns of high-level management as well as model developers. Visualization aids for the latter, to aid with debugging at individual node levels, are lacking.
5. We exemplify the deployment of PIQUE through two deployed use cases.
6. We provide an extensible metamodel of the PIQUE framework. The metamodel is designed with extensibility in mind.



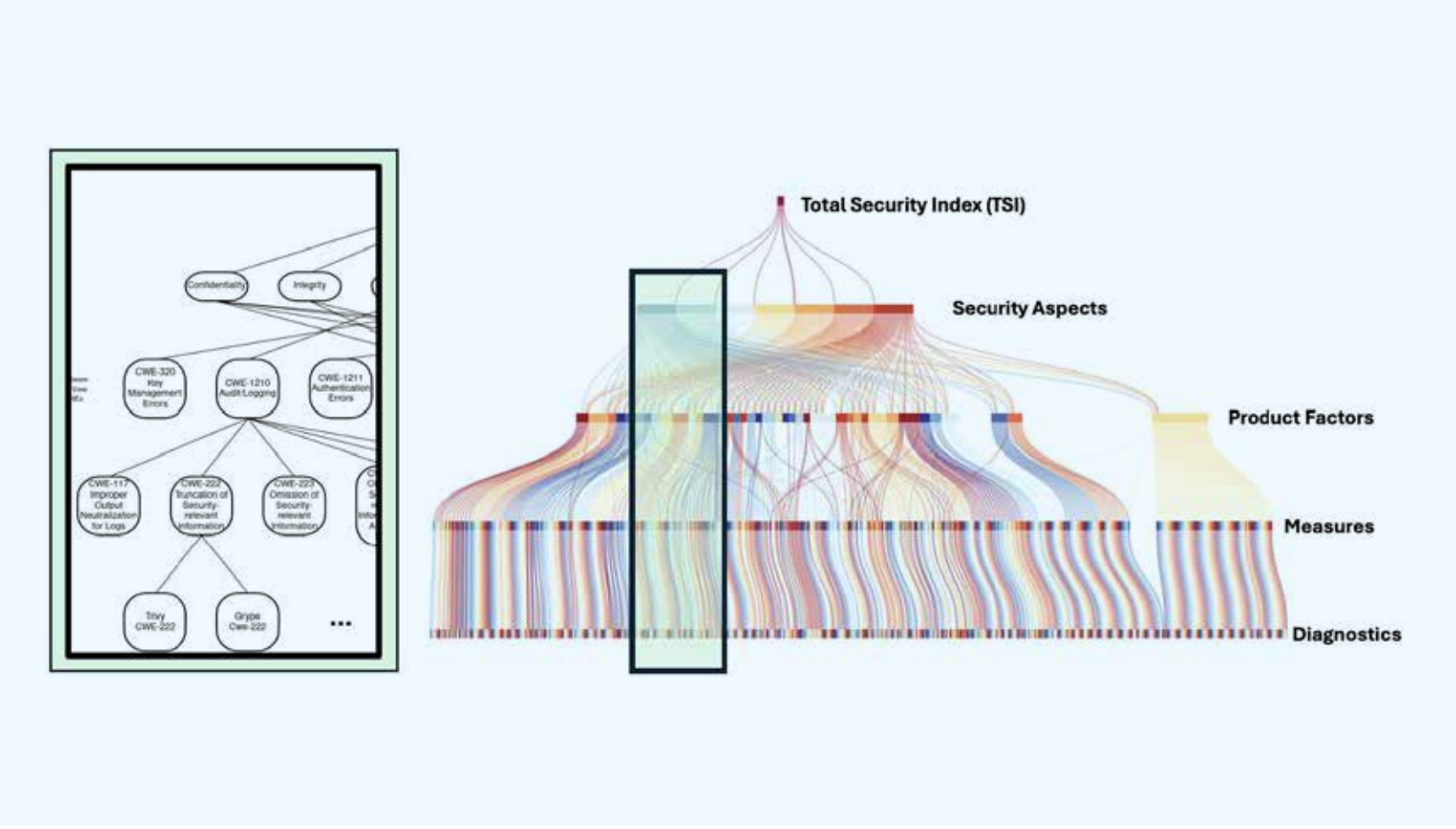
Process for generating an operational PIQUE model. From left to right, a model developer begins the process by using a generic model that is customized with QA attributes commensurate with the target domain (e.g., MS STRIDE), then the importance of the contributions of various attributes at lower levels is captured through a weighing approach. Finally, tools available in the domain are connected to the model to achieve full operationalization.



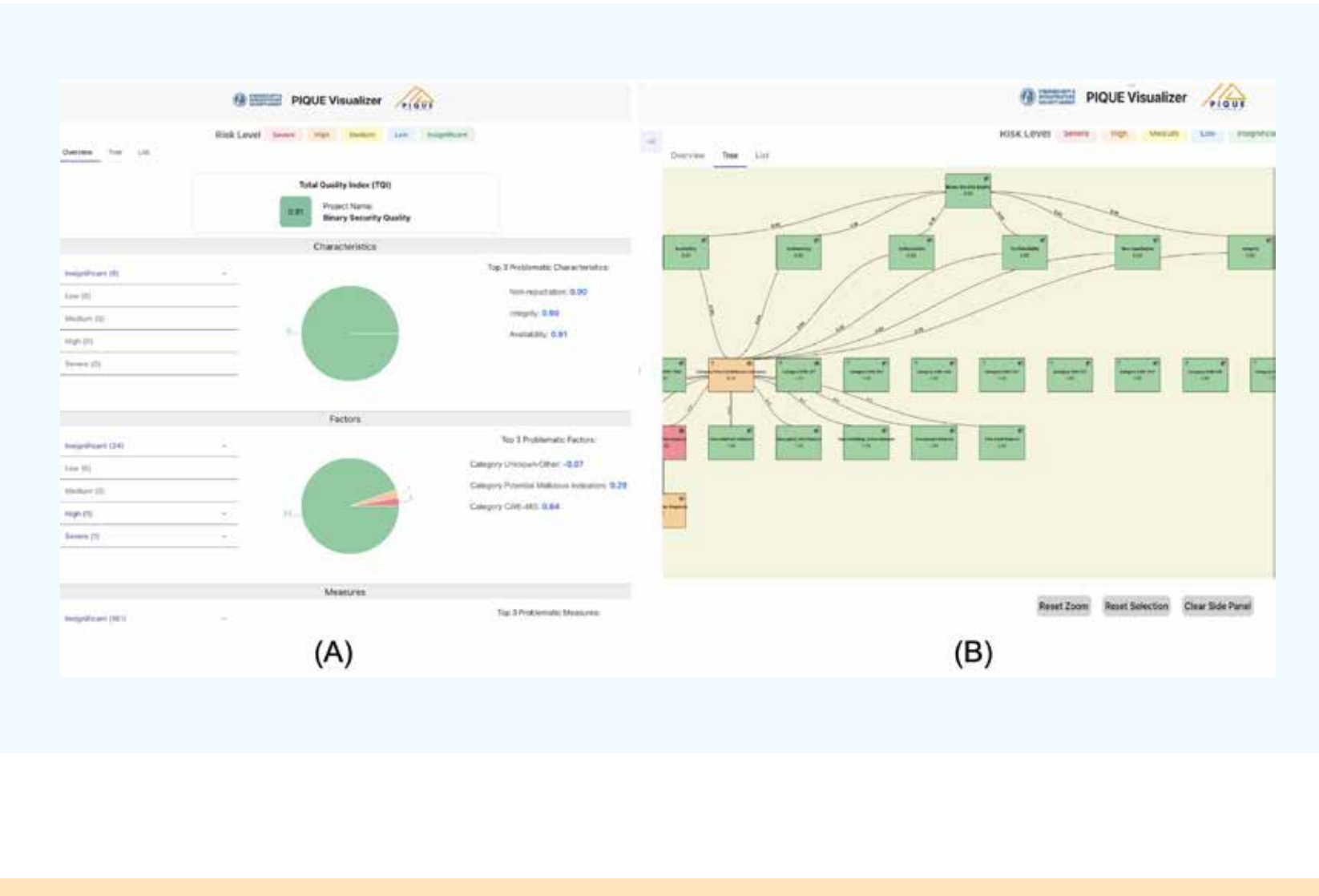
The PIQUE Framework metamodel. The structural model is drawn using the Unified Modeling Language (UML) where red dashed arrows represent interface realizations and black solid arrows represent class inheritance.

CONTRIBUTIONS

PIQUE contributes to the academic community because it offers a platform that can be used to experiment with new techniques to assess the quality of systems. PIQUE includes new aggregation techniques, machine learning capabilities, weighing of characteristics, and visualization. The practitioner community also benefits because many organizations are unlikely to devote resources to developing these frameworks. They instead use “out of the box” technology that can be deployed quickly.



Partial view of the SBOM security model. The right-hand side of the image displays the names of the various layers, spanning from the “Diagnostics” which represent tool outputs, to the Total Security Index (TSI) at the top of the tree that provides a holistic QA score. The complete SBOM security model contains 7 quality (security) aspects aligned with selected ISO/IEC 25010 standard (security sub-characteristics) and MS STRIDE, 42 product factors, 403 measure, and 806 diagnostic nodes at its lowest level.



(A) Visualization dashboard of high-level characteristics of a PIQUE model. Users can access pie charts and aggregated scores at the Aspect levels
(B) Visualization of lower layers of the PIQUE model. At the lowest level, developers and modelers can review actual scores produced by tools and the weights associated with the edges connecting hierarchical levels of the tree. This figure is courtesy of the Software Engineering Laboratory at Washington State University.

CONCLUSION

Finally, it is important to emphasize that future work in SQA is paramount given the proliferation of software technology. Everything is connected, from personal technologies to critical infrastructure, which creates a landscape where the ripple effects of a poorly constructed software component can propagate through the supply chain with unknown and untraceable consequences. For this reason, we must address software quality as a first class citizen and evangelize software quality by design. With PIQUE, we aim to continue to elevate the importance of software quality by incorporating newer techniques and technologies as they emerge. Significant improvements in machine learning and accessibility to a larger open source corpora of examples are compelling reasons to continue to evolve the quality assurance landscape.

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Clemente Izurieta, Derek Reimanis , Eric O'Donoghue, Kaveen Liyanage, A. Redempta Manzi Muneza, Bradley Whitaker, Ann Marie Reinhold