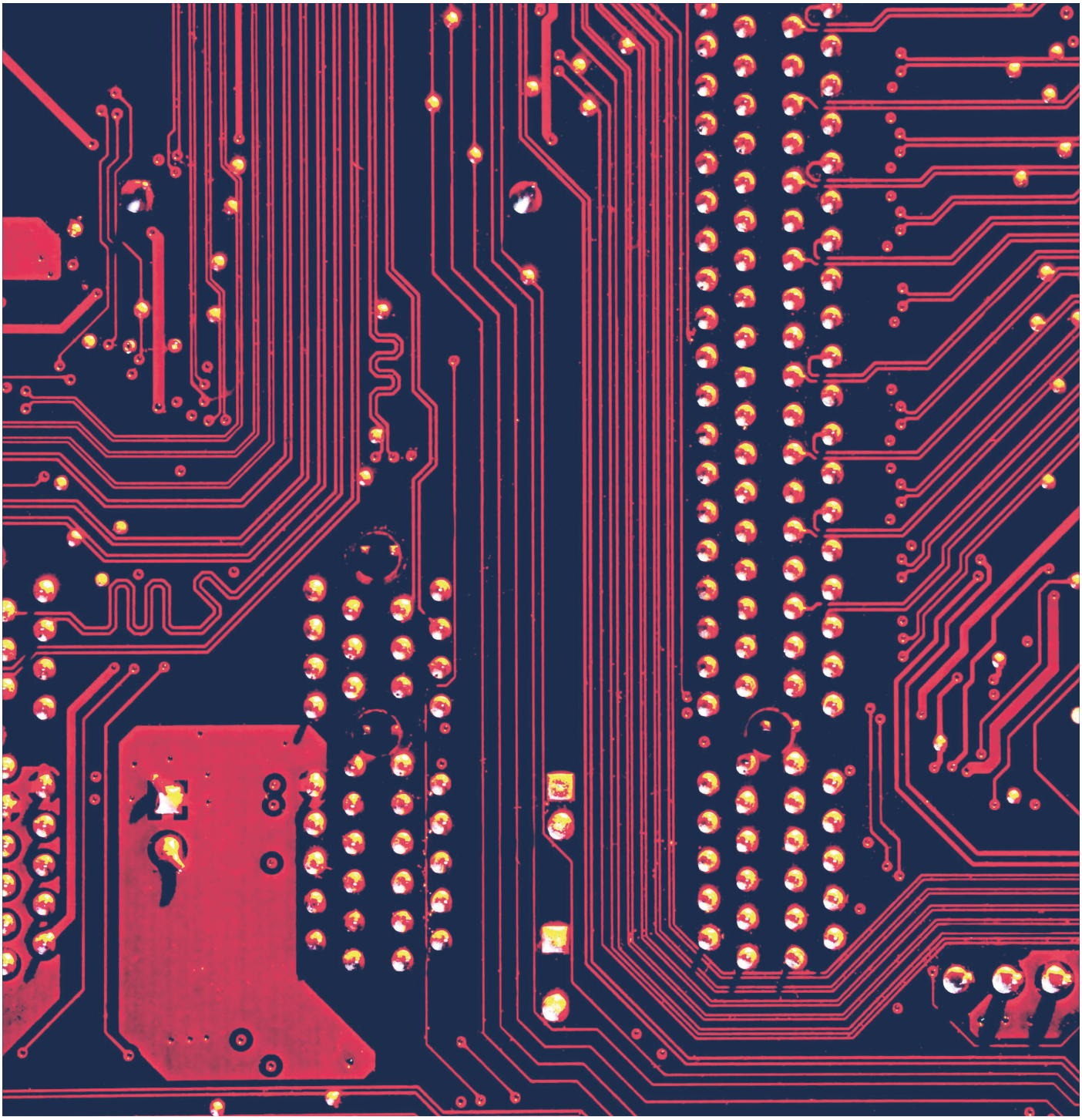

AI Testing AI

A Glimpse of Software Testing in the Coming Years

Testing Intelligent Products, Intelligently

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Executive Summary

How do you vision Quality Assurance (QA) domain in the future, say, a decade down the line?

Well, the World Quality Report (WQR) 2018-19 listed end-user experience — for the first time ever — as the top objective of QA and software testing strategy. And in the subsequent year, it reported that QA would require broader Artificial Intelligence (AI) skills to keep pace with the rapid growth of technology.

To say that technology is progressing at lightning speed would be an understatement. This, combined with the findings of the WQR, challenges the QA domain to push itself – to integrate advanced technologies into the processes to achieve maximum consumer satisfaction. As more 'intelligent' and 'smarter' products are set toflood the market, traditional test automation will fall short in meeting the requirements of AI, intelligent DevOps, IoT, and immersive advanced requirements.

Given that, test engineers need to evolve their test methodologies: AI and IoT based ecosystems, and immersive technologies like VR will get more mainstream and be integrated into products. The QA domain needs to include not just new tools but new approaches and strategies as well. Serverless architecture, containers-based applications, codeless/no-code platforms, distributed ledgers, edge computing – these are just some of the changes that will impact the way QA testing is done.

So, in the coming years, QA will move up in the Agile value chain, which will require both a mindset change and a cultural shift. It will be critical to have the right mix of people, tools, approaches, culture, and practices. In fact, QA will be in a continuous innovative mode.

This whitepaper tries to explore the topics around some teething questions related to the future of QA

Examples:

- What will the test automation frameworks look like?
- What evolution will we see in testing tools to meet the QA needs of AI and IoT-based applications?
- As enterprises go from being hierarchy-driven to data-driven, what evolution will we see in testing practicesfor Big Data?
- How will digital transformation and customer experience impact QA practices?
- What skills would QA engineers need?
- What will be the impact of tough data privacy laws on QA practices?
- How will non-functional aspects of modern systems be validated?
- What will be the transformation in the tools and practices?

Infusion of Intelligence:
The Rise of AI Products

Ever since its arrival, AI has been disruptive and has impacted – and still impacts – businesses across sectors.

Autonomous cars have become the 'next big thing' in the automobile industry, while the healthcare sector has seen the rise of ML-powered diagnostic tools. From 'intelligent' decision making to AI-powered software that guards global security, the market has seen the rise of intelligent products that go far beyond their basic functions. With the advent of deep learning, neural networks, and artificial intelligence, QA will encounter more challenges to effectively test these applications (products?).

This will give rise to a specialized AI tester.

This market will keep growing exponentially. A Tractica report predicts the global AI software market to attain massive growth by 2025. From $10.1bn in 2018, annual global revenue is estimated to increase to $126 bn in the next five years. In the next decade, the market will be inundated with products that have cognitive features, powered by AI and ML.

10.1 Billion 2018 **TO** **126 Billion** 2023

Global Revenue Projection of AI Software Market

Since 80% of testing is just a repetition of the checks the software already possesses, AI is better equipped to automate it and take it on efficiently instead of a human tester which needlessly inflates cost and effort.

Testing has progressed to become an automation-backed process, with Agile Testing shrinking the System Development Life Cycle (SDLC) to 2–3 weeks. Continuous Testing has combined accuracy and speed to deliver the best results. But with digitwal transformation becoming the norm, continuous testing will evolve to include intelligent algorithms that test in real-time,reducing the SDLC even further.

How will the onset of AI impact QA, testing tools and test automation? Traditionally applications are deterministic logic-driven. This means that for a determined input, there is determined output and hence, it is possible to predict output for a given input. AI-based models are probabilistic logic-driven. This means, there is unpredictability in the output for a given input. The output of an AI-based model depends on how the model was trained. What complexifies AI testing is that engineers generally know how to build/train an AI model, but don't know how the model works, to predict the output.

Primarily, we will see AI impacting the following areas of QA, but not limited to:

Visual testing:
AI will be used to identify UI or image patterns and design to identify visual bugs.

Self-healing automation frameworks:
The automation scripts will adapt to any changes made on the application UI. These automation frameworks will be intelligent enough to identify the changes madeto the UI.

Intelligent analysis of application logs:
AI models will be used to analyze application logs to identify all exceptions and then categorize them into bugs or system exceptions. The current manual analysis effort will be almost eradicated.

Test-case writing using AI:
AI models will be used to crawl through theapplication, identify logical endpoints, and write test cases automatically. The algorithms will also be intelligent enough to assign priority levels to the test cases and facilitate priority-based execution cycles.

Evolution of QA tools:
The modern-day testing tools will have libraries to support AI/ML-based test automation, including APIs for visual pattern identification. They will also have self-healing features. Since it will be difficult for one tool to meet all automation needs, QAs will use a combination of tools to achieve this.

The QA capability factor:
QA engineers will have to understand big data, data science, and statistical modeling to test AI-based applications. Going ahead, QAs will also be expected to increase their technical proficiency.

Intelligent analysis of performance bottlenecks:
AI models will be used in “performance engineering” where the tools will analyze the data collected through performance testing and predict/identify the bottlenecks in the applications. The modern-day performance testing tools will have libraries to support it.

Evolution of performance testing tools:
Performance testing tools will evolve to accommodate the emergence of Big Data. Performance testing and functional testing of Big Data equire testers to work with a changing schema and varying data sources. Accurate data representation in the extracted sample is a challenge in the case of large sets of data. Inaccuracy will mean a reduced capacity to self-learn or self-adjust in the AI product. When AI is introduced in the testing process, testers will be able to rely on a process that evolves to accommodate this challenge.

We will also see the onset of a variety of AI-based bots (such as chatbots). The tools and frameworks to test these solutions will mature even more.

To summarize, AI will make the testing life cycle shorter and smarter. While AI will bring a lot of efficiency to testing, many QAs across the globe will be required to level-up their skills and learn data science, statistical modeling, and other allied subjects.

Data Quality is Key for AI

Data is the key to train and test AI models. The testing team must ensure that the data used to train the model is not the same as the data used to test the model. This is because the objective of training data is to make the model learn a pattern. However, the test data should have some degree of variability to ensure that the model has learned the pattern. The same sets of training and test data lead to perfect predictions in testing and hence may also lead to incorrect predictions in production by the model.

Given the above criteria, product intelligence has extensive dependence on data. Their self-learning and predictive capabilities are derived from the abundance of large data sets. This leads us to the conclusion that testing these products will require altering or improving upon traditional testing methodologies, including knowledge of data science and big data. A QA should be well adept with data mining tools, data quality assurance best practices, and well-versed with programming languages like Python and R.

The challenges associated with data input and analysis demand highly specialized tools to navigate and arrive at meaningful patterns. Static and dynamic data sources can also pose complications regarding data quality, correctness, and variety.

Heterogeneous data sources are another typical point of challenge. For products with cognitive features, data behavior at scale is a huge concern.

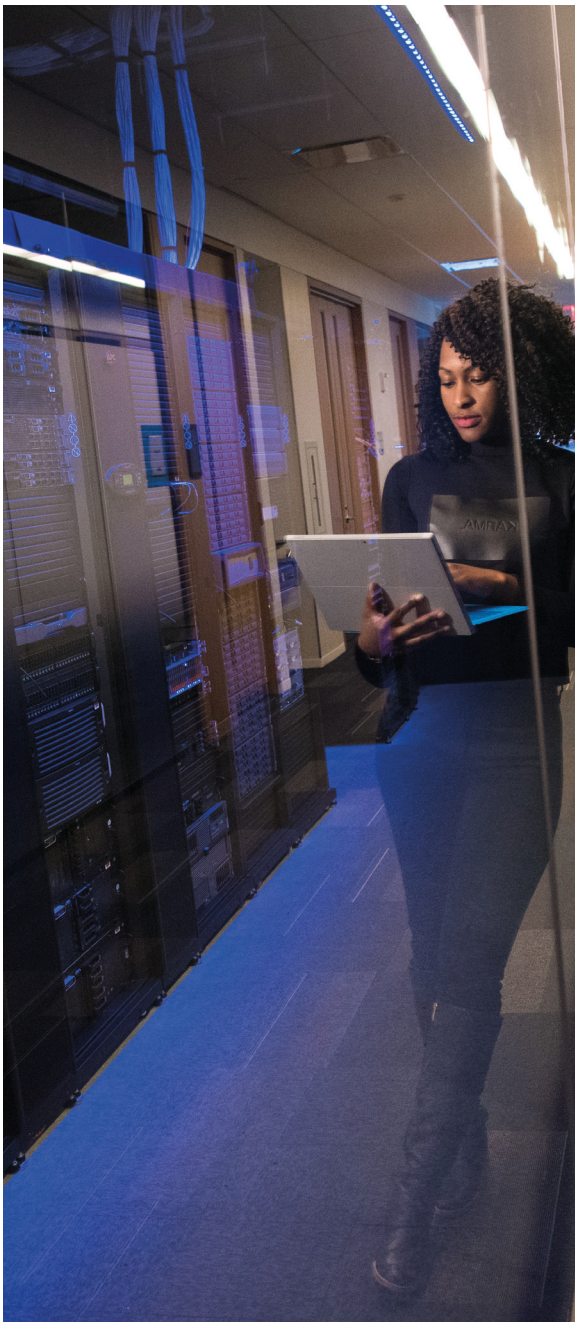
Analytical Quality Assurance: Better Data Quality Drives Better Decision-Making

Data availability and storage have become simpler and cheaper in the last 10 years. This abundance of data has resulted in the need to adopt better data analytical capabilities to drive better decision-making. For businesses tobecome truly digital, it is critical for operations to become data-centric.

Data collection and processing strategies of giants like Google, Facebook, and Netflix have consistently yielded successful results. Netflix's success story is founded on its highly complex personalization algorithm that analyzes userdata effectively to produce customized content., Compared to its competitors like Hulu and Amazon, Netflix's customer retention rate is at an impressive and unbelievable 93%. Data is now being recognized as an Enterprise Asset and warrants attention at all levels in an organization.

With the advancements in technology, businesses are shifting from a hierarchy-driven to an information-driven model. Organizations across the globe now find themselves in need of data-driven decision-making since data is plentiful and accurate decisions are critical (as proven by Netflix's retention rate). he right data leads to the right insights, consequently leading to the right decisions. Extracting useful and meaningful data gives an insight into consumer behavior, trends, and preferences. This will help enterprises – product-based and service-based – to make key business decisions.

This also means that businesses will invest a lot in the development of systems that collect and analyze data.



Data Analytics is the process of analyzing and interpreting meaningful patterns in data monitored from an ongoing analytical algorithm, product, or process. As of now, analytical QA, which - in simple terms - analyzes the quality of data and data processing, is in its nascent stage. The extracted meaningful patterns are then used for decision-making. Data Analytics uses statistics and mathematical models to quantify the performance of the overall process or algorithm. One important factor to note in the entire analytical process is the quality of the collected data. If the collected data is wrong, then it may also result in wrong decision-making.

Additionally, the algorithm that analyzes the collected data must be validated for correctness. Hence like any other software system, data collection process, analytical algorithms and their implementations need the continuous attention of a software quality analyst.

Analytical QA is sure to become more mainstream in the near future as most of the products developed by enterprises will also be used to collect vast amounts of user or field data. The QA team will test the analytical process and find bugs that could potentially turn the carefully gathered data for business intelligence and decision-making into an un-usable mass of data. Analytical QA will require testing in the nuances of not only what can go wrong with collecting the data but also on how data can be incorrectly interpreted, potentially leading to inaccurate decisions.

Algorithms already ‘decode’ and classify large amounts of structured and unstructured data stored in data lakes to provide meaningful insights and help us draw a complete picture. The next decade, however, will see data validation driven further by advanced ETL algorithms, making the process of decision-making a data-oriented one rather than a people-oriented one. Data collection will also receive a boost as this will enable enterprises to collect the right data that will eventually lead to effective decision-making.

Analytical QA will also impact the QA value chain, from staffing to testing tools. Technical staff with knowledge of big data, data science IoT, statistical models will be needed. New tools supporting Analytical QA will emerge, though some tooling solutions are already present in the industry. Cloud-based tooling solutions supporting automated processing and analysis of voluminous data will also emerge. MS Azure and AWS are currently working in this direction. We will also see many custom or open source solutions (using available tools) in the industry or Analytical QA.

Along with tools, we will also see that advanced technology will support the improvement of data quality at the source. For example, with biometrics, cameras, and facial recognition, the identification of individuals has become more accurate at source, leading to better decision-making.

Analytical QA strategies will also follow a different approach to QA, including analysis of key data sources, data profiling, creation of master data, and formation of new KPIs to measure success. We will also see the emergence of new mini roles within QA teams, such as data architects and modelers.

Experience Quality Assurance:
Predict End-User Experience

Quality Assurance impacts the user experience. When things don't work, users question their understanding and develop superstitions and inefficient workarounds.

When Ubisoft started the pre-release promotions of the adventuregame 'Watch Dogs', game enthusiasts were com- pletely taken in by the trailers. The user experience that the game offered was exceptional. But when Ubisoft released the game in 2014, expectations fell flat. It failed to engage the gaming community, deeply disappointing most avid fans.

Watch Dogs' did not have many flaws. While its gameplay and graphics were impressive, it failed to captivate gamers in its narrative. The result: Despite fulfilling some of the biggest criteria in the gaming industry, the game was nowhere near as successful as it was expected to be.

Predicting user satisfaction in the gaming industry is not an easy task; multiple factors determine the success of a game. While gameplay and graphics are at the top of the list, gam- ing is an experience that touches many human aspects, thus making narrative, lore, voice acting, and character development equally important.

Quality testing of the technical aspects of online and offline games is mostly automated. However, experience testing is still people dependent. Dedicated game testers verify all the 'soft' aspects of games like narrative and lore, which is time-consuming.

In the coming years, we may notice approaches with abilities to predict the user experience of a product. Some work is already being done in this direction, but it will become more mainstream with the onset of approaches and tools for pre- dicting end-user experience.

Data about user engagement and experience is highly valued in the prototype stage, which will help companies take a data-driven approach towards whether to approve or abandon a product.

Deploying AI-powered intelligent algorithms can automate experience QA to validate the products against set criteria.

This is an area that, in the coming years, will see rapid development and investment as it has the potential to save cost, time, and effort for any industry. Platform-agnostic apps and games stand to gain from automated experience QA, as the number of bugs/glitches are almost directly proportional to the number of platforms they are supported on. With ad- vanced technologies like AR and VR gaining popularity (most video game companies already provide that option, 'Batman: Arkham Asylum' by Rocksteady Studios being a prime example), the need for stringent QA for seamless performance is of high importance.

Ensuring the success of a product before it hits the market will become a game-changer soon. Validation testing of user experience will become a requirement to save time and money.

The Onset of IoT Testing

IoT devices and wearables have acquired a large chunk of the market in recent years.

The world is more connected now, and enterprises as well as individuals are integrating IoT devices in their functional spaces.

IoT involves real-time data processing and perfect communication among a vast array of smart devices, hardware, and software. This means that we must ensure a flawless perfor- mance of all components of this array. Although testing ofIoT devices has progressed, it still leaves much to be desired. There are challenges in network security that must be addressed without fail, both for enterprises and individual customers. Data privacy in all the connected modules poses a difficulty, with end-to-end encryption becoming a necessity.

As IoT testing goes mainstream, it will act as a catalyst in the development of tools and frameworks to support the testing of connected devices. Quality testing of IoT devices must cover this and a wide array of other potential fallibilities. Auto- mation will play a significant role in IoT testing in the coming years. Faster deployment of products and services apart, sophisticated testing models also address the concern of tighter data security and seamless performance quality.

As previously covered, advanced algorithms performing data analytics will ensure a better quality of data compared to the results of traditional testing methods. Automation also ad- dresses the problem of scale. As IoT integration becomes the norm, conventional testing methods fall short of fulfilling the requirements in the specified time, whereas automated testing can better support the IoT ecosystem.

Conclusion:
The Customer is at the Heart of Testing

Have you ever been in situations where customers are not happy with quality even after significant efforts to ensure it? The system under testing conditions may have been work- ing flawlessly, but customers may not feel that "wow" factor while using the system. The result is a very average customer experience.

Why does this happen? Are we missing a trick here?

To understand this, let us quickly see how testers and customers perceive quality, and understand why testers must devel- op their thinking beyond the traditional functionality-centric (or product-centric) model of quality engineering.

Most quality engineers perceive quality as excellent product functionality and follow a "product-centric approach". Here, the focus is primarily on ensuring correct product functional- ity, followed by performance and security, and finally on pro- viding a delightful user experience. This ap- proach generally results in seamless product functionality but does not guarantee the right user experience.

Why? We need to understand the customer's perception of quality.

The customer's perception of quality is driven by their end-user experience. User experience is a matter of percep- tion, and perceptions can be managed by a unique quality engineering approach that places its focus on the end-user.

Product-centric vs. User-centric approaches

It is imperative to understand the UX needs of our customers and define a quality engineering approach that is aligned with this need. If our quality engineering approach is product-centric and ignores end-user UX needs, then it may result in an unsatisfied customer. So, instead of being product-centric, our quality engineering approach should be user-centric, as shown below:

The user-centric approach of quality has the highest focus on end-user experience. It should be noted here that a user-cen- tric approach does not mean we deliver a functionally buggy system. This simply means that testing of the system must be done by keeping the end-user experience in mind. Instead of product functionality, the user experience drives testing and test design and takes the highest priority in the overall quality engineering thought process. This approach is also known as Customer Experience Assurance.

To conclude, Quality Assurance (QA) is at an inflection point today. The onus, however, is on organizations to reimagine their QA processes to create benchmark value and gain competitive advantage.

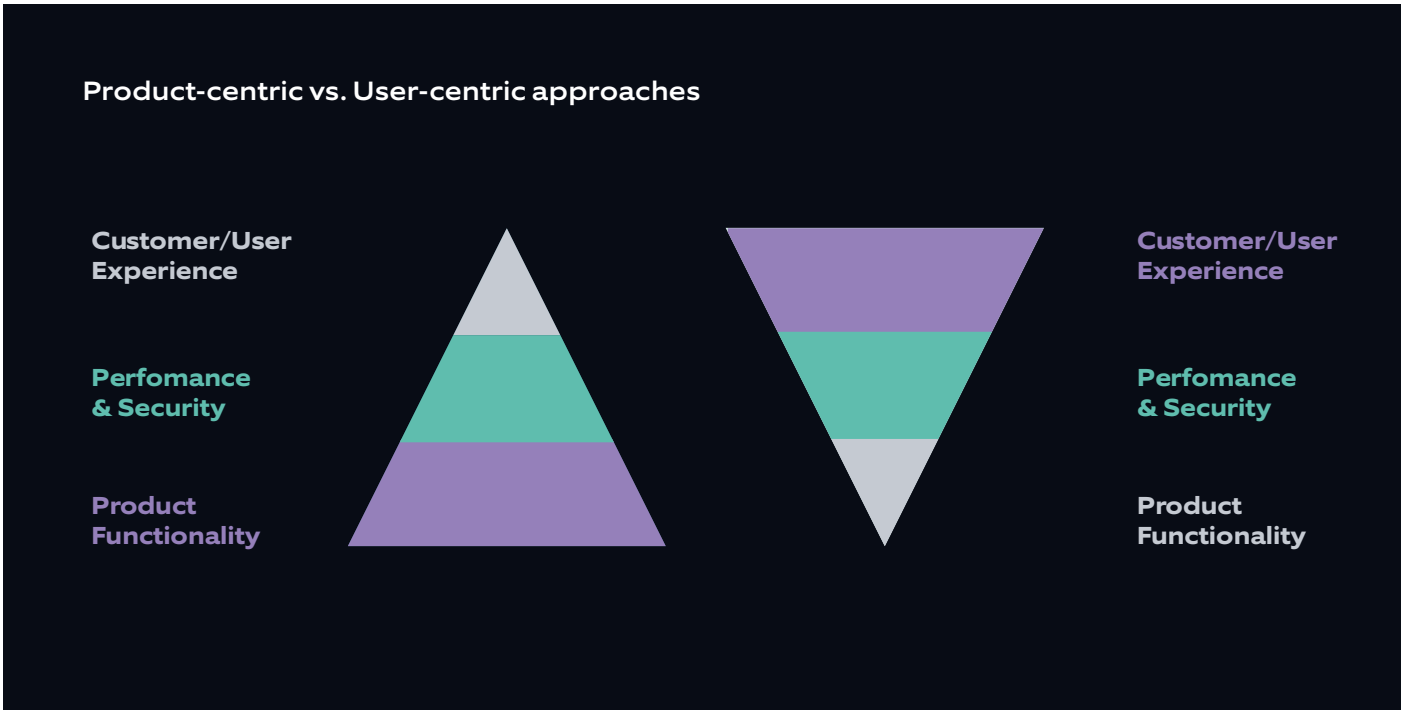


Figure 2: Product-centric vs. User-centric

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