Artificial Intelligence, Microservices, xAPI, Human Performance Assessment, and Adaptive Training: How Five Buzzwords are Applied to Real Problems

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ABSTRACT

The United States Department of Defense has typically relied on turnkey solutions delivered by companies with proprietary capabilities and minimal rights. This acquisition approach has vendor locked the government into one platform, slowed innovation, and prevented the ability to quickly respond changing needs. As multi-domain threats develop, the need has emerged for the military services to pull together innovative buzzword capabilities from disparate companies to rapidly assemble unified interoperable solutions.

The US Navy's (USN) Center for Surface Combat Systems (CSCS) is responsible for delivering surface ship combat systems training to achieve surface warfare superiority. CSCS needed to develop a solution that increased skill acquisition, skill retention, and Sailor confidence for computer network technicians. Responding to this request, Aptima elicited the support of another company already developing immersive virtual environments for CSCS to develop a functional training solution in less than nine months called the Simulator-Harnessed Intelligent Performance Measurement and Adaptive Training Environment (SHIPMATE). SHIPMATE was created by integrating five buzzword capabilities into a "performance optimization wrapper" that utilizes microservices to enhance existing simulation and courseware platforms. This wrapper supports real-time adaptive training, harnesses xAPI data generated by learner actions, parses that data into human performance assessments, applies Artificial Intelligence (AI) algorithms to assess proficiency, and recommends scenarios to learners they are best positioned to attempt. With this performance optimization wrapper, other organizations are able modernize existing training platforms by pulling together any buzzword capabilities they require into one unified solution.

ABOUT THE AUTHORS

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INTRODUCTION

The United States Department of Defense (DoD) has typically relied on turnkey solutions delivered by companies with proprietary capabilities and minimal rights. This acquisition approach has vendor locked the government into one platform, slowed innovation, and prevented the ability to quickly respond changing needs. Recent trends reveal signs of United States near-peer adversaries expanding their political control, military capabilities, and are specifically targeting to increase their access to weapons of mass destruction (GAO Report, 2018, p.9). With these multi-domain national security threats, it is imperative we take pull together innovative buzzword technologies and rapidly assemble unified interoperable solutions to increase our operational advantage today. However, cutting edge technology is often not mature enough for prime time use or is not able to be integrated into a platform already adopted by an organization. Once the innovative technology is ready for operational use, the implementation can be months or even years later and can result in the delivery of an obsolete solution. In order to overcome these problems, there must be a better understanding of the problem space, an increase in collaboration between government and industry, and the tools to support progress forward.

With the pace at which adversaries' technology is evolving, the operational advantage continues to be eroded daily. When a comprehensive solution is demanded, often there is not any one company that can satisfy all the requirements. This necessitates companies coordinate to develop the ideal combination of highly specialized capabilities and technologies. However, once the right mix of companies and offerings is found, progress slows again when technical discussions begin, and companies try to determine the appropriate integration approach. The source of this challenge typically ranges from the need to protect Intellectual Property (IP) to the rigmarole of the integration process and this becomes exponentially more complicated as the number of companies involved increases. Once these details are finally solidified, the arduous process of integration begins.

Unfortunately, by the time a fully functional solution is ready, the warfighter may have already lost significant ground to the adversary. This process is inherently faulty, but what if it were reimagined to prioritized developing capabilities that add value to any final solution, regardless if it were solely composed of that company's offerings or not? This paradigm shift provides the foundation for a scalable and sustainable impact when applied across the services and can increase the operational advantage for the U.S. over its adversaries.

THE PROBLEMS OF TOMORROW ACROSS THE SERVICES

Each military service produces documents that outline current adversarial trends and predictions of problems on the horizon. These documents contain insights about the types of solutions the services believe can prevent and mitigate the impacts of the challenges they are facing.

The Air Force

In the U.S. Air Force 2030 Science and Technology strategy, increasing the speed of battlespace understanding and decision-making to act faster than any adversary is one goal outlined. Artificial intelligence (AI) and predictive analytics are described as essential to this effort. The Air Force plans to utilize AI to overcome challenges such as sorting through noisy and unstructured data from dissimilar sources, limited training data for machine learning, and the high levels of trust required to support lethal combat operations (USAF Science and Technology Strategy, 2019, p. 7). There are many benefits to using AI, but for the Air Force to achieve its goal of sorting through noisy data, missing data, and achieving high levels of trust, there must be an increased focus on **enabling AI with the ideal algorithms given the data sets**. Without the use of AI algorithms tailored to the specific use case with surgical accuracy, the Air Force risks a breakdown in trust between the human machine teams, jeopardizing lives and missions.

The Army

The Army Vision for 2025 and Beyond revolves around eight key characteristics; (1) Agile; (2) Expert; (3) Innovative; (4) Interoperable; (5) Expeditionary; (6) Scalable; (7) Versatile; and (8) Balance. Of these eight, five are directly identified with training needs, specifically agile, expert, innovative, interoperable, versatile, and balance. Two recurring themes underpin these key training needs, adaptability and modularity. Within the Army vision, adaptability takes on numerous forms, such as training scenario adaptation (e.g., creating training scenarios that adapt to evolving requirements across all theaters of operation), individual Soldiers adaptation (e.g., Soldiers and leaders capable of continuous re-orientation and adaptation within increasingly unpredictable environments), and organizational adaptation (e.g., adapting will require innovative thinking, including developing new concepts and applications and optimizing our use of existing capabilities). In each case there is some level of expected uncertainty where training provides the opportunity for each entity to engage and achieve beneficial outcomes. While it might not be readily apparent, modularity goes hand in hand with adaptability. Just as no battle plan survives first contact with the enemy, Soldiers must adapt and move forward by making a decision, followed by another decision, and so on. Within a training event, this requires **a modular design that enables an adaptable series of events to unfold and drive a series of responses**. For a training solution, this requires modular components that can be rapidly assembled and swapped depending on changing requirements. A statement in the Army vision sums it up well, “As it applies to technology and materiel solutions, increased innovation should drive the development of new tools and technologies, enabling the Army to obtain capabilities ahead of competitors and adversaries” (The Army Vision, 2015). For the Army to achieve its vision for adaptive solutions, industry capabilities and technologies must be modular and able to quickly integrate when responding to immediate operational needs.

The Navy

The U.S. Navy is incorporating innovative learning technologies and methods to support Ready Relevant Learning (RRL), aligned with the vision of Sailor 2025, to ensure Sailors are provided the right training at the right time, in the right way. In a statement to the Senate Armed Services Committee (SASC) Vice Admiral Burke declared RRL provides a “holistic approach to training our career enlisted force, which will accelerate learning for a faster response to rapidly changing warfighting requirements in increasingly dynamic operational environments. Legacy training does not take full advantage of existing and emerging technology for knowledge-transfer.” In recent years, performance assessment in Navy training has gone from status quo, to a major focus. This is a step in the right direction, but progress cannot stop there. If training still takes on one-size-fits-all approach, it misses an opportunity to truly accelerate Sailor learning. A primary enabler for determining Sailor readiness and life-long learning is **human performance assessment supported by a flexible data protocol**. The Navy has recently invested resources to apply a data protocol to their current RRL content conversion efforts, but for the Navy to achieve its vision, it must establish a standardized data model and increase the level of granularity required for human performance assessment. By building systems around flexible open standards, the Navy can reduce lifetime costs of the system and the technology components may be refreshed as needed by any vendor through a focus on interoperability by design.

The Need

To increase the operational advantage, we must predict and solve tomorrow's problems, today. This can be accomplished by merging innovation with proven technologies and enabling tighter collaboration between companies within industry. We must operationalize buzzword capabilities and provide them at the rate technology is moving.

FIVE BUZZWORD CAPABILITIES

As more conferences are attended, new research is conducted, and mainstream technology articles are written, there are certain terms that grow in popularity. As these words are spoken, investigated, and quoted more frequently they trend into a realm of buzzword status. While this should create an opportunity for shared situational awareness across the industry and unify a lexicon, it often can reduce the understanding of the buzzword by conflating its definition and purpose. In this section, a definition and purpose for each of these buzzwords will be provided in the context of training with modeling and simulation as a focus.

Artificial Intelligence (AI)

AI can be used to solve extremely complex problems across a very diverse set of domains. When large amounts of valid data are collected or extremely knowledgeable experts are available, AI algorithms can provide decision makers with invaluable insights. AI definitions can take on many forms depending on the specific use cases, but generally it is a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation. (Kaplan & Haenlein, 2019, p. 15). In essence, AI is focused on learning, taking action, and producing results, often at a level of throughput unattainable by human cognition in a timely manner. This is perhaps its greatest advantage, raw and disparate data from various sources can be turned into valuable information within seconds that otherwise would have gone unknown. However, it has become increasingly necessary to evaluate the validity and granularity of the data feeding AI models.

Microservices

Addressing the need of solving tomorrow's problems today without impacting today's solutions requires a new approach to systems architecture focused on agility within this new cross-service and company collaborative environment. One architectural approach that has shown the ability to support hyper-growth and enable rapid shifts towards new market demands at companies like Netflix and Amazon is also built around Decentralized Governance (Fowler, 2014). This approach is broadly known as the microservices architectural style, depicted in Figure 1, is a method of developing software applications as a suite of independently deployable, small, modular services in which each service runs a unique process and communicates through a well-defined, lightweight mechanism to serve an overall goal (Huston, 2018).

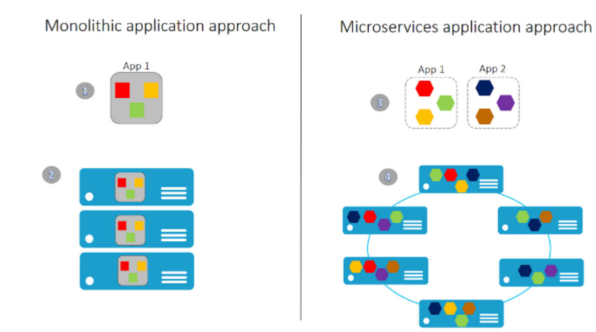

Figure 1: The Microservices Approach

As traditional applications mature, they are typically scaled by simply increasing the number of instances of that application available to serve the user, which is known as horizontal scaling. However, microservices introduce a new concept of vertical scaling as they may be scaled independently. This allows for tailored applications composed of the most appropriate services for the user based on their needs at that time.

Through these properties of microservices, this architectural style is uniquely positioned to support today's need while being capable of evolution to solve tomorrow's problems.

Experience Application Programming Interface (xAPI)

Communication protocols exist to connect software programs and allow them to interoperate. As modeling and simulation have become more widely adopted for training purposes, a need arose to capture data that is more granular than completion scores. Advanced Distributed Learning (ADL) developed xAPI to offer an avenue for developers to identify specific actions of interest they want data on. They define xAPI as a specification that lets you capture (big) data on human performance, shown in Figure 2 to the left, along with associated instructional content or performance context information. xAPI applies human (and machine) readable "activity streams" to

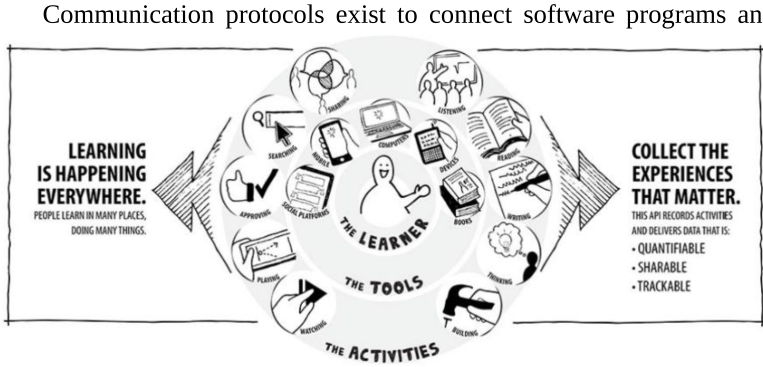

Figure 2: The xAPI Approach

tracking data and provides sub-APIs to access and store information about state and content (https://adlnet.gov/projects/xapi/). The xAPI data outputs from user actions are then utilized for performance assessment.

Human Performance Assessment

Within the context of training, human performance assessment can be viewed as an interpretation of raw numbers from computations generated by specific data sources (Stacy et. Al, 2006). These assessments are contextually aware of the task, environment, conditions, and standards to compare the raw outputs against. Additionally, the raw data outputs must be collected at an appropriate level of granularity, when compared against the performance standards to produce assessments that adequately differentiate between learner knowledge and skill nuances. The accuracy of the human performance assessments is critical to the success of the adaptive training.

Adaptive Training

Adaptive Training is defined as training in which the problem, the stimulus, or the task is varied as a function of how well the learner performs. The typical an adaptive training system can have the following five components, adaptive variable, performance measurement, adaptive logic, error standard and difficulty level, and results. (Kelley, 1969). However, adaptive training feedback can take many forms and often can be viewed over various time steps. For example, inner-loop training can be feedback delivered within seconds to minutes during a training experience, middle-loop training can be after action reviews provided minutes to weeks between training experiences, and outer-loop training can be training recommendations over months to years of a career. Adaptive training can also look at altering the use of instructional strategies for the specific training objectives. It is also necessary to mention AI is one popular application of adaptive training, but AI is not the only way to accomplish this approach.

APPLYING FIVE BUZZWORD CAPABILITIES TO A REAL PROBLEM

With the services demanding the implementation of various buzzword capabilities, Aptima responded to this challenge by applying five of their cutting-edge research and development technologies to a specific use case at the U.S. Navy (USN) Center for Surface Combat Systems (CSCS). The mission of USN CSCS is to develop and deliver surface ship combat systems training to achieve surface warfare superiority. CSCS delivers specialized training for officer and enlisted Sailors who are required to tactically operate, maintain, and employ shipboard and shore-based weapons, sensors, and command and control systems utilized across the Navy.

The Goal

The overarching goal of this effort was to identify any factors inhibiting Sailor knowledge and skill acquisition, develop a training solution that accelerates learning, increases retention, and bolsters Sailor confidence before Fleet deployment.

The Solution

To aid CSCS in its advanced learning initiatives, Aptima evaluated the factors inhibiting Sailor skill acquisition and from those results developed SHIPMATE, a Simulator-Harnessed Intelligent Performance Measurement Adaptive Training Environment. SHIPMATE was created by integrating five buzzword capabilities into a “performance optimization wrapper” that utilizes microservices to enhance existing simulation and courseware platforms. This wrapper supports real-time adaptive training, harnesses xAPI data generated by learner actions, parses that data into human performance assessments, applies AI algorithms to assess proficiency, and recommends scenarios to learners they are best positioned to attempt.

SHIPMATE Applied

A high-level concept of operations (CONOPS) is helpful when orienting to a system workflow and provides insight into how the capabilities work together.

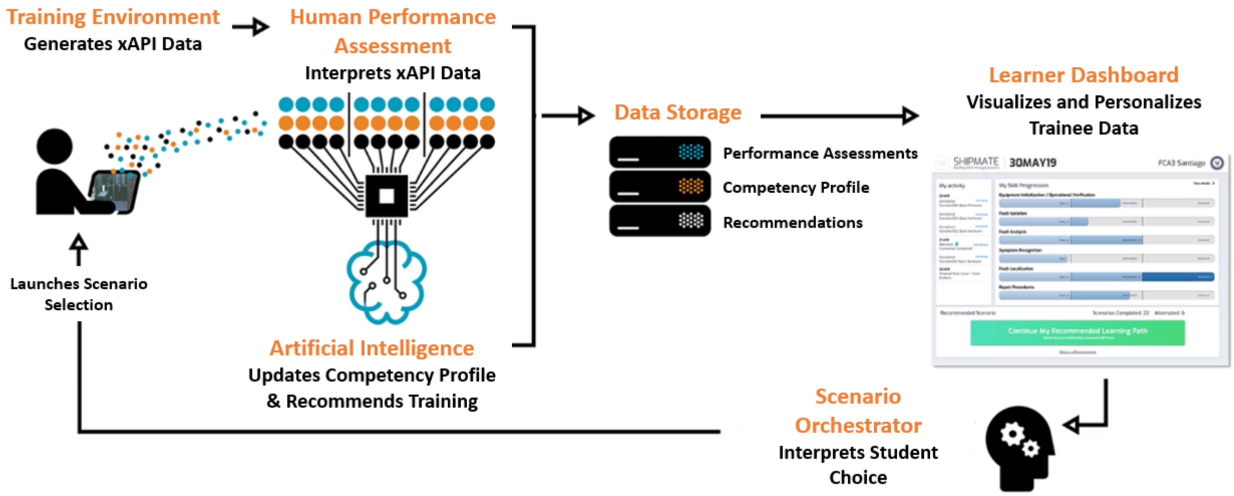

Figure 3: SHIPMATE CONOPS

Integrating five buzzword capabilities requires applying innovative science and engineering practices. Learners are supported in the environment with **adaptive training** via inner-loop feedback in the form of hints. These hints are catered across three levels of strength, geared toward their real-time needs and are unique to each specific scenario. This ensures the learners are not solely dependent on instructor support during these activities and are able to complete dynamic training scenarios asynchronously. As learners attempt tasks and perform actions in the training environment, raw data is generated.

This data is a result of entity interactions at the level of granularity necessary for capturing human performance. One of the key open standards utilized is **xAPI**, which provides a rich ecosystem of existing specifications as well as a design for extensibility. The intersection of science and engineering is realized by combining community provided content through an online registry with the reuse of an existing open standard for interoperability and new 3rd party systems. This data is sent in the form of xAPI statements (i.e. actor, verb, object) and is extensible to meet the assessment requirements of any domain. This means the training environment does not bear the burden of running computations and instead the **human performance assessments** are responsible for context modeling the scenario and the learner's performance. For example, if the learner flips a switch in the environment, an xAPI statement of "*Learner X, toggled, switch Y*" is produced by the training environment and the assessments determine the level of correctness for toggling the switch at that time given the expected performance. The result of this computational process is the conversion of raw data messages into meaningful assessments of performance that are stored into a data base and are ready for AI decision making.

The **AI** satisfies middle-loop adaptative training where feedback is provided to the learner in the form of recommendations for the next training scenario. To accomplish this, the AI first uses data mining algorithms to develop and store probabilistic updates to learner competency profiles. SHIPMATE uses data mining to continually update Sailor competency profiles to make precise training recommendations while keeping learners within their zone of proximal development (Vygotsky, 1978). Using these competency profiles, the AI then generates an instructional policy to plan out and recommend the next optimal scenarios to accelerate growth. These recommendations are stored and presented in the dashboard for the learner to choose their next step. Once a scenario is selected, the scenario orchestrator stores the learner choice and launches the next scenario through the training environment to complete the cycle. Each time this process is completed the AI algorithms capture more data and the confidence of the probabilistic model for each learner increases. Additionally, if skills are not utilized as time goes on, the AI algorithms contain a skill decay model to predict and update the level of atrophy.
To further enhance the scalability of this solution, an innovative **microservices** engineering-based approach was taken to prioritize a modular and open architectural design. This aligns with the need to enable individual contractor capabilities to operate independently without the constraint of coordination, while still allowing development of collaborative solutions based on government demands. This approach allows a small team to own a full end-to-end piece of the overall application and enables fully independent vertical modules to be modified, removed, replaced, or replicated without affecting other features in the system. By having a modular design focused on open interfaces, development can quickly progress by coupling components both explicitly and only where it makes sense for the

design. This allows for increased parallel development and testable independent components. While this solution was developed with these five buzzword capabilities, the approach used here can be applied to any number and mixture of capabilities. Utilizing microservices blended with science-based training strategies facilitates new possibilities for innovation able to match the speed of technology.

THE IMPLICATIONS AND AFFORDANCES OF APPLYING BUZZWORD CAPABILITIES

Implications

There are numerous implications for both the government and contractor when this approach is used to integrate buzzword capabilities into one solution. Let's first consider the government implications from two different viewpoints, the leadership and end users.

The government leadership is responsible for casting a vision, lining up funding, and providing oversight. Once leadership has identified the solution requirements and level of funding, a complete solution should provide the following things (1) a short timeframe between award and implementation, (2) an increase in performance, decrease in resources spent, or ideally both, (3) tangible results and updates along the way, and (4) ability for the solution to be easily maintained over time to respond with changing requirements.

With this type of training solution:

- Existing systems can be quickly combined to meet current needs and modified to respond to changing needs.
- Scenario-based training can be conducted asynchronously without being fully dependent on an instructor and leverages them to spend their time working one-on-one with the learners.
- The leadership receives real-time evidence-based reports on learner proficiency across competencies.
- The flexible xAPI data protocol is utilized with a growing community of adopters within the U.S. DoD.

The government end users are responsible for interpreting the vision of the leadership, executing on demand, and maintaining situational awareness. Once end users have understood the vision, an effective solution should support their training in the following ways (1) identify and close gaps in current performance, (2) attain and maintain the new level of expected performance, and (3) provide tools and insights that enable learners to invest in their career.

With this type of training solution:

- Inner-loop feedback provided in real-time accelerates knowledge and skill acquisition.
- Middle-loop AI-based training recommendations provided between experiences improves learning retention.
- Personalized visualizations provided continuously depicts a self-evident view of current proficiency levels.

The contractors are responsible for understanding government challenges, meeting the requirements, and reducing risks. Once the solution requirements and level of funding have been established, a compelling solution should provide the following things (1) a comprehensive response that achieves the government's goals while differentiating the solution from other competitors, (2) delivers results and exceeds government expectations, and (3) gains access to the organization and opens up the potential for continuing work down the road.

With this type of training solution:

- The ability to quickly respond to government problems with a complete solution is increased.
- The threshold required to access and work with leadership and end users on relevant problems is lowered.
- Integration efforts are less complex, less labor intensive, less costly, and reduces risk.

Affordances

This solution can be applied to each of the services to solve their problems of tomorrow, today. For the Air Force looking to sort through noisy and missing data, an open architecture with a microservices approach allows for the ideal AI algorithm to be used on the available data sets. For the Army looking to increase adaptability across their soldiers, scenarios, and organization, a modular design blended with an adaptive training approach allows for end products to be tailored to each use case. For the Navy looking to deliver the right training at the point of need over the course of a Sailor's career, the xAPI data protocol combined with granular human performance assessment allows for an accurate depiction of Sailor competency profiles.

As each of the services seek to increase their operational advantage and gather information about the current buzzwords capabilities available in the industry, it is imperative to ensure each of the capabilities have been developed to work together and can rapidly form the most innovative and mature solution for the warfighter.

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