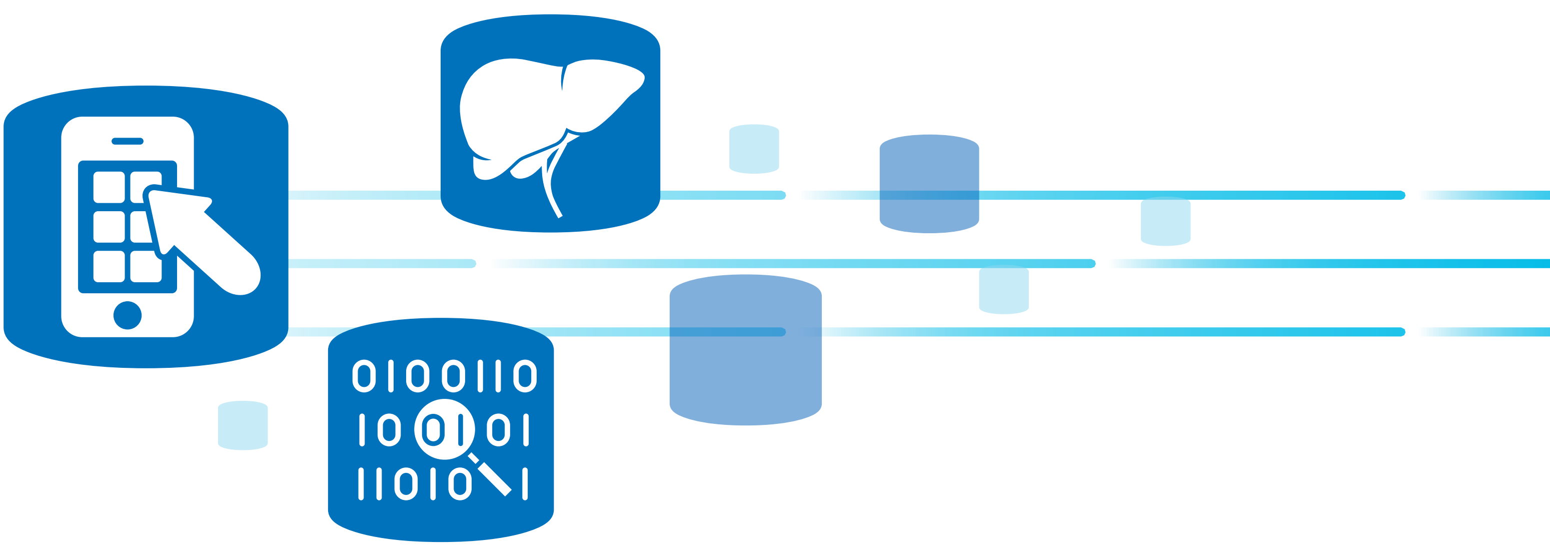
The A to A Digital Platform

Ultrasound's advantages as a real-time, low-cost, non-ionizing, portable imaging modality has led to wide-scale global adoption. With increasing focus on radiation exposure and cost effectiveness, in combination with improved imaging, quantitative capabilities and enhanced portability, ultrasound growth continues to accelerate. While this growth has many benefits for patients and the health system, it can be a stress to ultrasound users and departments that are solving a wider range of clinical problems and managing increased volume while also working to improve patient satisfaction.

To help customers with these demands, GE Ultrasound has designed A to A, a new AI-based digital platform that is aware of and interacts with the digital ecosystem around it to provide the next level of assistance for ultrasound users. The direct result of a smarter, more aware ultrasound system, the A to A digital platform serves as the perfect complement to GE Healthcare's cSound™ imaging architecture.



Introduction

Some stories begin at the end. The goal of the A to A digital platform is assistance. Just as a surgical assistant provides the right tool to the surgeon exactly when needed, our vision for the ultrasound machine is to be an amazing assistant for the user, delivering the right tool at the right time, anticipating what the operator needs, and helping to ensure no detail is missed.

Yet every story needs a beginning. The A to A digital platform begins with awareness. Just as a self-driving car needs to be aware of its surroundings to navigate a complex world, the ultrasound system needs to be aware of the digital world that surrounds it, interacting with smart devices and the cloud, collecting and analyzing big data, and using machine learning to not only scan, but be actively aware of what is being scanned.

To make the story a reality, the A to A digital platform consists of three key areas: ***App Assistant, Analytics Assistant,*** and ***Anatomical Assistant.*** Each delivers new and distinctive features that are benefiting clinicians and their patients today.

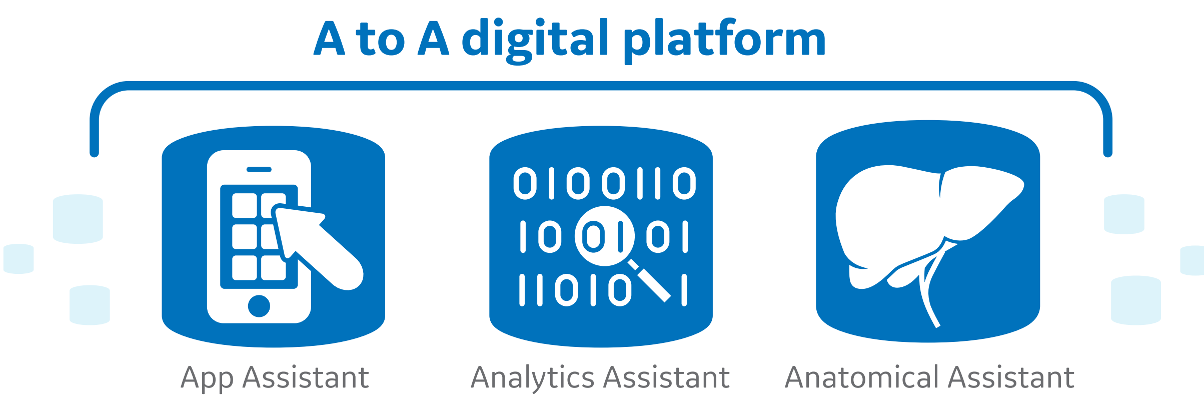


Figure 1 – There are three distinct, yet interconnected capabilities of the A to A digital platform.

App Assistant

App Assistant leverages awareness of the digital world around the ultrasound system, including smart devices and cloud technology, to realize new ways to assist the user.

While we generally think of smart devices as small, portable electronics that we carry with us, a smart device is actually defined by its ability to connect to other devices via standardized wireless communication protocols. As such, the A to A digital platform makes the ultrasound system itself a smart device that interacts with smart tablets and phones to achieve new capabilities. Two of its capabilities are described below.

The convenience and power of smart devices impact many aspects of our daily lives and the A to A digital platform leverages them to do the same for ultrasound.

Photo Assistant helps clinicians confirm findings, document clinical symptoms, and provide comprehensive reports.

This is achieved by the seamless integration of anatomical photos into an ultrasound study. Clinicians can use an Android™ smartphone or tablet to photograph relevant scanned areas that may influence the exam and give anatomical context. These photos are transmitted to the LOGIQ™ ultrasound system and are included with the diagnostic images of the exam. They can be annotated and even shown side-by-side with an ultrasound image.

The photos are not stored on the smartphone or tablet, but strictly transmitted from the device to the ultrasound machine.

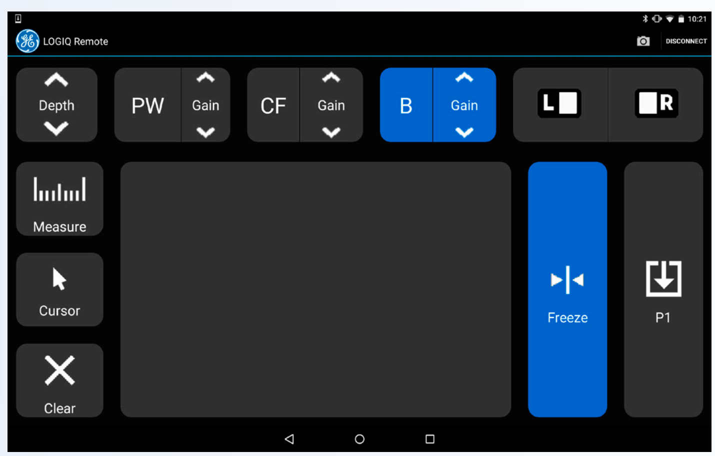
Furthermore, if the photo is a barcode or QR code, Photo Assistant translates the code into its alphanumeric code, allowing automated filling of the patient ID using a scan of the patient's wristband or the code on a patient's requisition form.

Remote Assistant enables the user to operate the ultrasound system from a smart tablet or phone. The ultrasound machine is often moved to the patient, who may be in a room not conducive to the ideal placement of the scanner. Thus, the operator is challenged to ergonomically scan the patient with one hand and control the machine with the other. Remote Assistant enables the controls to "decouple" from the system and move with the user. Having such flexibility is particularly welcome in an interventional suite where the crowded space around the scanner makes remote control a highly practical tool.

The app user interface allows many scanner functions to be controlled including:

- Major modes
- Depth
- ROI placement
- Measure
- Freeze/store
- Gain
- Dual Image

Photo Assistant can be used to accurately document a variety of situations including the location of the probe for a critical image; the swelling of one limb in relation to the other limb; a point of pain for the patient; the appearance of a physical bump, lump or bruise; the extent of redness in the leg; and bandages on a patient that limit the exam.



Remote Assistant (tablet version shown) provides direct access to the main imaging modes, dual image as well as scanning parameters such as gain, depth and scale. The pad area provides trackball equivalent movement, vastly extending what can be done with the app including ROI placement and measurements. The phone version has fewer controls and is optimized for single-handed operation.

Smart devices are easily and securely paired to the ultrasound scanner by scanning an on-screen QR code and accepting the pairing. Specifically, Bluetooth® wireless technology is used as the communication protocol between the ultrasound system and the tablet or phone. This short-range protocol allows App Assistant to be dynamically paired with another smart device. When a new device is connected, the previously connected device is automatically disconnected, but paired devices are remembered so that subsequent connections are even easier.

In addition to smart devices apps, App Assistant is also aware of and able to interact with cloud-based apps (also known as services). GE has partnered with Tricefy® to provide three important services: sharing images with patients, collaborating on cases with colleagues, and cloud-based archiving and exam review. The seamless integration between the App Assistant and these services means that no extra hardware or software is needed on the scanner or in the department.

Patient image sharing enables image clips and reports to be shared securely and instantly to patients. Patients simply receive a text message or e-mail with a link. Patients can then share the information with family and friends.

Cloud-based archiving enables exams to be securely archived and viewed from anywhere at any time on an internet-connected device. These exams can even be reloaded onto the scanner via DICOM® Q/R.

Collaboration allows easy and immediate sharing of the exam with referring physicians, colleagues, and other experts. Collaborators use internet-connected devices to view the exam data. Optionally, the exam data can be anonymized.

From a technical standpoint, cloud-based apps have increased access to storage and computational resources. While the most accessible version of a cloud-based app is deployed outside the institutional network, it is also possible to deploy certain cloud applications within an institutional network. This is sometimes referred to as an on-premise cloud, fog or edge deployment.

In addition to the exciting benefits today, we believe the future will see a growth in relevant apps and services that add value for ultrasound users.

Analytics Assistant

Analytics Assistant leverages data that is generated each time the user interacts with the system—every click of a button, every touch on the touch panel, and every movement of the trackball. The collection of this large amount of usage data (big data) provides a new level of awareness and the analysis of this data provides potential insights that can lead to new ways to assist departmental workflow and even future product design.

Data Driven Design

In a world where data is increasingly more available, data is driving more decisions. For example, the design of the LOGIQ E10 Series user interface is based on an analysis of usage data collected from more than 30 different institutions and included more than 1.6 million user operations. This data provided important insights that were investigated more deeply and ultimately led to key decisions.

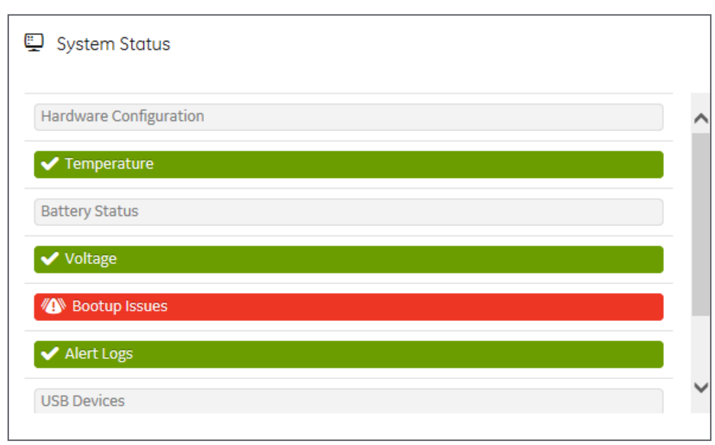
Some examples...

- Two new context-sensitive keys were added near the trackball to move higher use touch panel controls closer to the user's hand.
- Fewer than 3 in 1000 user operations involve the TGC. That finding, plus the improved uniform imaging enabled by the cSound Architecture, led us to convert the TGC from a hard-to-clean physical control to a digital control on the touch panel.
- Since more than 10% of user operations involve the alphanumeric keyboard, it was retained on the main surface of the user interface rather than placed in a drawer.

Data collected by the Analytics Assistant not only improves equipment design, but the existing features below also assist customers by providing insights to optimize the maintenance and utilization of their assets.

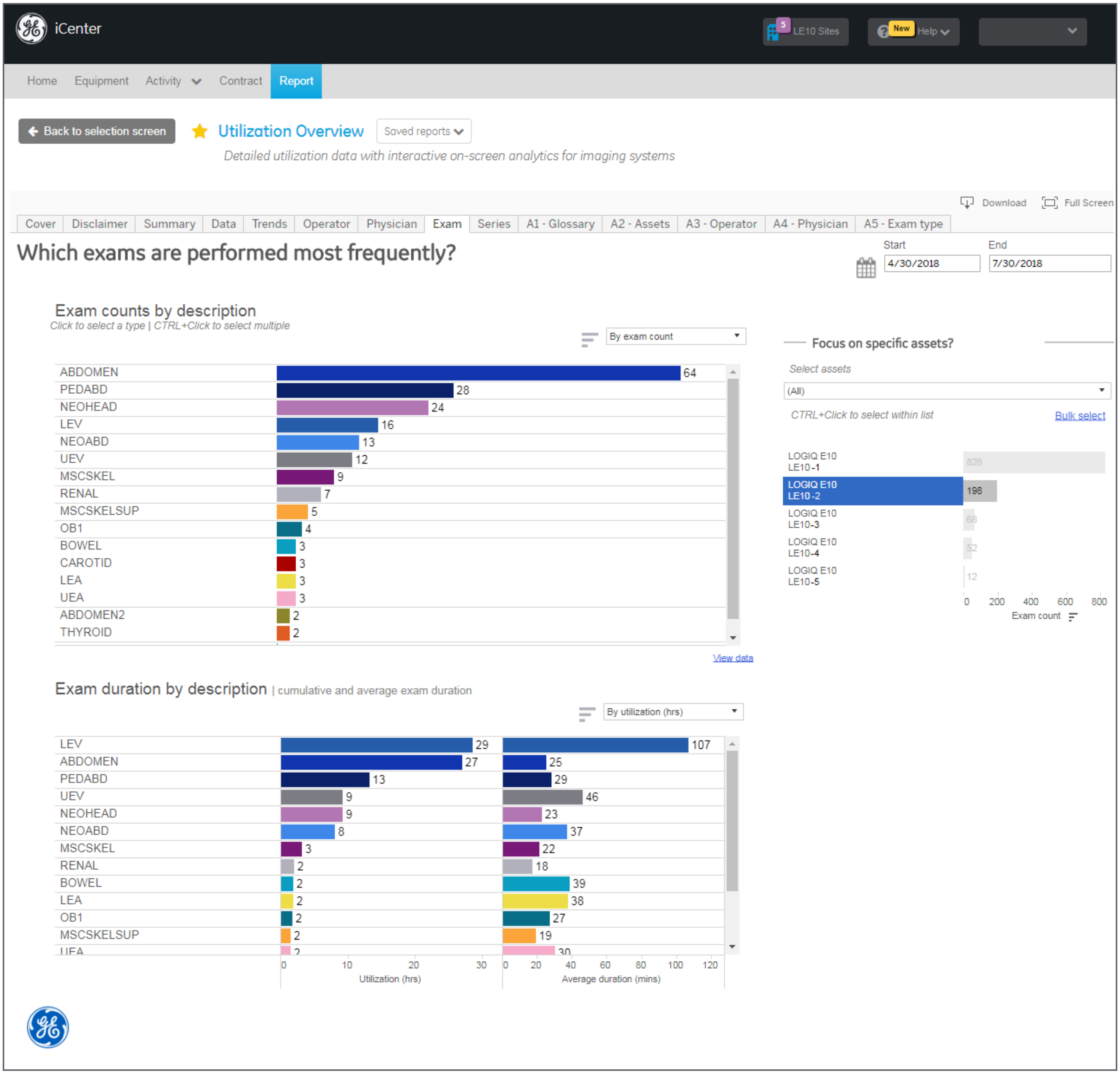
System Health Dashboard

Visualize system health alerts and service status onboard the LOGIQ E10 Series. Gives GE service engineers and in-house staff secure, easy access to critical system health data to guide maintenance and repair, including connected probes.



Utilization Reports

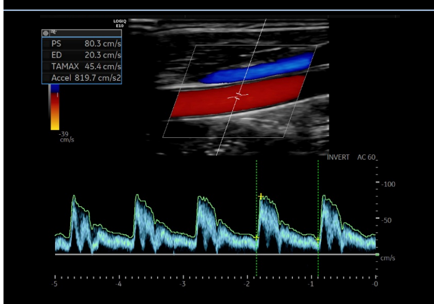
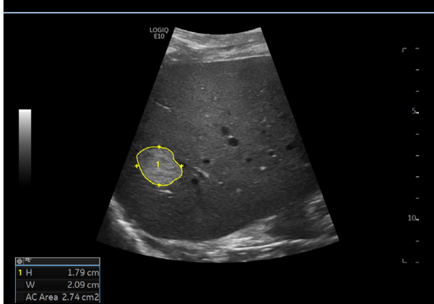
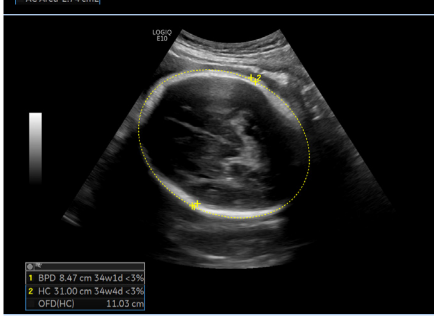
Machine Data features on InSite connected systems allow users to securely view system utilization, service, and exam performance data on the iCenter™ portal to optimize departmental operations. This data includes the number and types of exams, the length of the exams, and daily utilization. By viewing this analysis, users can develop insights to help improve the operational efficiency of the department. While the data shared with GE Healthcare does not include patient identifying information, it can optionally include variables, such as the operator of the exam, that can enrich the level of the analysis.



As tools to analyze data become more sophisticated and the source of data becomes broader, the breadth and depth of potential insights continues to expand.

Anatomical Assistant

The A to A digital platform enables the ultrasound machine to be aware of *what* is being scanned in order to provide anatomical-based assistance to the user. Four current features illustrate this concept.

Sample Image	Feature and Description	Classification and Detection
	***Breast Assistant*** – Breast Assistant, powered by Koios DS,™ automatically provides an AI-based quantitative risk assessment that aligns to a BI-RADS ATLAS® category and likelihood of malignancy (LoM). After measuring the lesion manually or via Auto Lesion Segmentation (see below), the user selects the Koios button, and the risk assessment appears in two seconds or less. This proprietary algorithm is based on more than 400,000 clinical images – providing decision support for the clinician and helping to improve departmental consistency.	Automatic, machine-learning based LoM classification.
	***Doppler Assistant*** – The system analyzes the image to determine the location and direction of vessels in order to automatically place the color ROI and the Doppler gate in the appropriate location and to steer them in the correct direction. The awareness extends to whether a given vessel is a vein or an artery, allowing the system to choose a vein even if both an artery and a vein are present during a lower extremity venous exam, for example.	Manual view classification (user indicates that the current view contains vasculature) and automated structure detection.
	***Automated Lesion Segmentation*** – The user identifies a breast, thyroid or liver lesion by clicking on the lesion and easily expanding or shrinking a graphical circle that appears centered about the clicked location to encompass the lesion. The algorithm then segments the lesion, providing a trace of the lesion boundary and the corresponding area. In addition, calipers are automatically placed that correspond to the height and width of the lesion.	Manual view classification (user indicates that the current view contains a lesion) and semi-automated structure detection (user indicates the sub-region containing the lesion).
	***OB Measure Assistant*** – The user identifies an image as a view appropriate for measuring the head circumference (HC) and biparietal diameter (BPD), the abdominal circumference (AC) or the femur length (FL). The system then automatically segments out the appropriate structure from the image and annotates it with the associated measurement.	Manual view classification (user indicates that the current view contains a particular fetal structure) and automated structure detection.

What these system features all have in common is that they are making decisions based on the awareness of the anatomical content of the image. Anatomical awareness can come in three distinct forms:

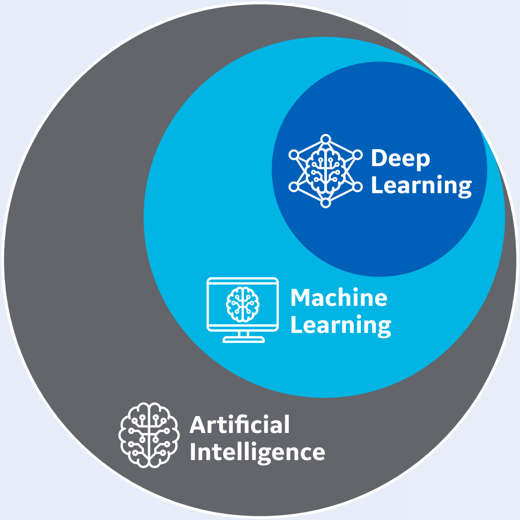
Anatomical View Classification is the ability to identify that an image belongs to a certain anatomical view. While theoretically there are an infinite number of anatomical views in ultrasound, the reality is that there is a finite number of standard views, each with some level of variability based on the orientation of the probe, pathology, and patient to patient differences. The number of potential views can be further limited if the exam type (abdominal or thyroid, e.g.) is known.

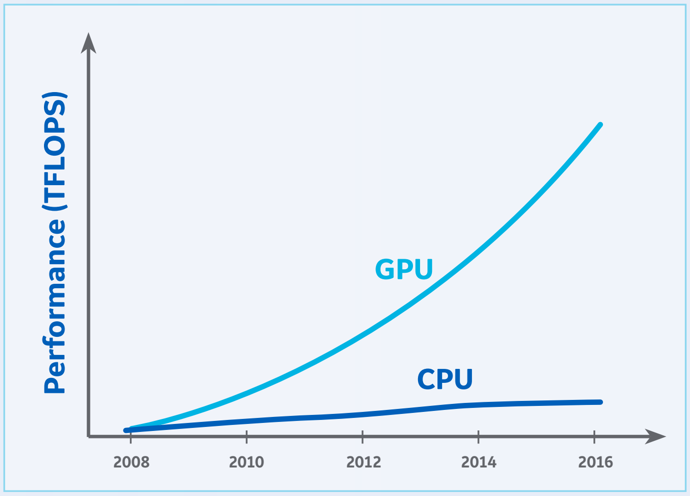
Anatomical Structure Detection is the ability to detect individual structures within an image or volume. In ultrasound, view classification would typically occur as a prelude to structure detection. For example, when viewing the liver to kidney interface, potential structures could include liver, kidney, diaphragm, gallbladder, skin and fat layer, IVC and aorta. Within the liver, internal vessels and lesions could be considered sub-structures.

Anatomical Structure Classification can be performed once a structure or sub-structure is detected. For example, once a breast lesion is defined, it can be classified as a particular shape such as oval, round or irregular. As anatomical structure classification starts to align with a diagnostic determination (such as likelihood of malignancy), it can be referred to as Decision Support.

The technology behind anatomical awareness is varied and can include traditional image processing techniques. However, the reason it holds such potential is that machine learning and deep learning, subsets of the field of artificial intelligence, are particularly well suited to both classification and detection. While much of the image-based work to date in machine learning and deep learning has been performed on photographic data, the principles apply to medical imaging as well.

Artificial intelligence is simply the ability of machines to simulate human intelligence. In *machine learning*, a subset of AI, the machine not only performs the detection or classification task, for example, but also discovers the features or rules for doing so (versus being supplied with a set of features or rules). *Deep learning* is a technique of machine learning in which the machine-discovered features or rules are represented in an artificial neural network that mimics the function of the human brain.





(Source: NVIDIA)

Figure 2 – Artificial intelligence is a concept that dates back to the 1950s. A subset of AI, machine learning, started to flourish in the 1990s and then deep learning, a subset of machine learning, started to emerge in industrial applications in the 2010s in part due to the growth in GPU computing power as well as the advances in deep learning tools and techniques.

As an example, let's assume we want to determine which of the standard views of the heart is currently being scanned. In this case, we can consider each of the standard views as a classification. We can collect a large number of cardiac images and annotate each one with the appropriate classification. We are then able to provide these annotated images to a computerized neural network which learns the features within those images that allow successful classification. This is the learning phase. Then, when presented with a new cardiac image, the machine learning algorithm is executed to infer the classification.

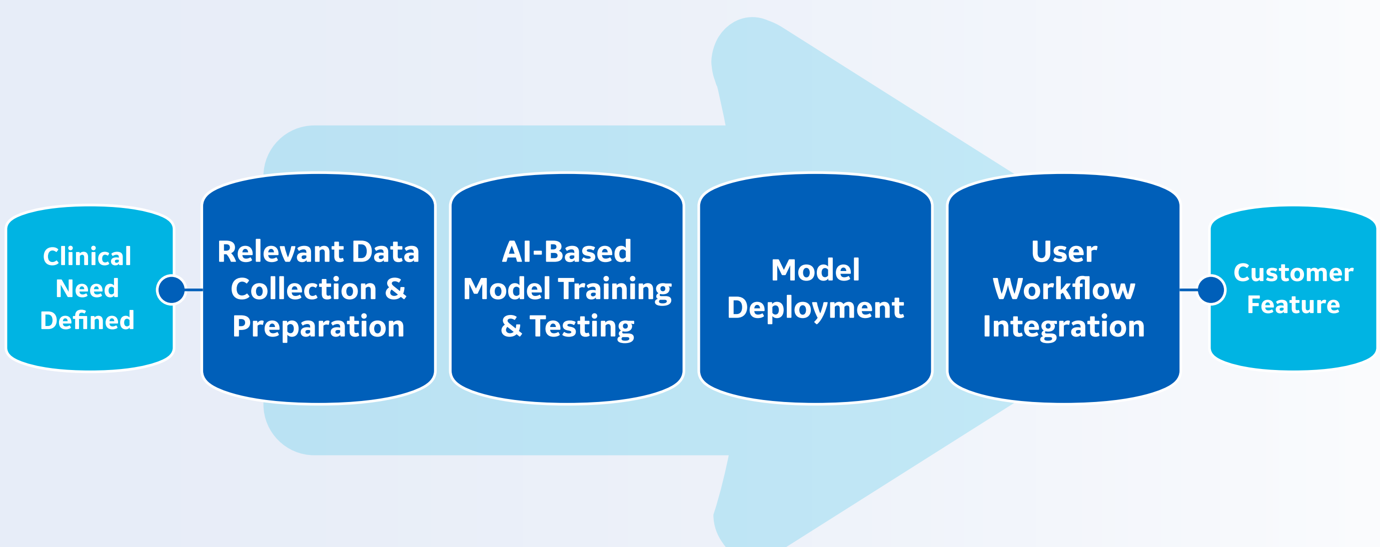
One does not have to extend the imagination very far to consider other future possibilities that may arise from increasing awareness.

- Detecting the anatomy under a color Doppler ROI (aorta, e.g.) and setting the imaging parameters appropriately for maximum color Doppler performance without user interaction
- Classifying the current image (long axis kidney view, e.g.), detecting an object of interest within the image (kidney, e.g.) and measuring it, all without user interaction
- Classifying a thyroid lesion based on its likelihood of being malignant or benign

While these are very specific examples, the list of known possibilities is far more extensive and we firmly believe there are possibilities yet to be imagined. As a comparative point, consider that GPS (location awareness) allowed us to know where we are on a map and we immediately understood the assistance it could provide in terms of navigating the world with a smarter map, but early on we did not see the full scope of impact. Today runners use it to track workouts, caregivers use it to track the location of dementia patients, and researchers use it to track the movement of wildlife. We are excited to both work on the known ways that anatomical awareness may assist ultrasound users and to discover the yet unknown ways that awareness will continue to change ultrasound.

The AI-based, A to A digital platform is the framework that enables anatomical assistance today and into the future.

AI Development Overview – Data is collected that is relevant to a particular clinical need. The data is prepared such as classifying different types of images or segmenting parts of images. Some of the data is set aside for training a new model and some of it is set aside to test the resulting model. To develop an AI-based algorithm, an appropriate model is chosen for training. During the training phase, the machine learns the model weights that optimize performance across the training data set. The resulting model is then evaluated with the data set aside for testing. Iterative adjustments are made until the model shows clinically acceptable performance. At this point the model needs to be deployed so that it can make inferences, or predictions, on new data. Making this a seamless part of the user workflow enables adoption of this new feature by operators of the ultrasound machine.



Edison is GE Healthcare's intelligence offering comprising of applications and smart devices, including ultrasound machines, built using the Edison platform. This platform enables GE Healthcare's internal developers and select strategic partners to design, develop, manage, secure and distribute advanced applications, services and AI algorithms quickly. Anatomical Assistant is *powered by Edison.*

In the automotive industry, the goal is clearly to create self-driving cars. But it takes the combination of many individual pieces to collectively facilitate the larger goal. Some of these individual pieces are being deployed in cars today, such as lane drift notification and accident avoidance systems. A 'standard' car, by becoming aware of the lanes and aware of the vehicles around it, is able to provide assistance to the driver.

Existing features of Anatomical Assistant such as lesion segmentation and Doppler Assistant are analogous to such intermediate advances in the auto technology. But the A to A digital platform is built with the longer-term goal of providing the user with the increasing levels of assistance. At the heart of the platform are high performance NVIDIA™ GPUs that have the computational power to perform the inferencing required to execute machine and deep learning algorithms. The platform also allows connectivity to 'off scanner' computing power (whether in the cloud or on premise) in order to run AI algorithms that are not resident on the scanner. Since the development of all future AI applications requires data, the platform also has tools to facilitate easy data collection from clinical partners who want to provide it, again leveraging cloud connectivity to gather images and other machine data.

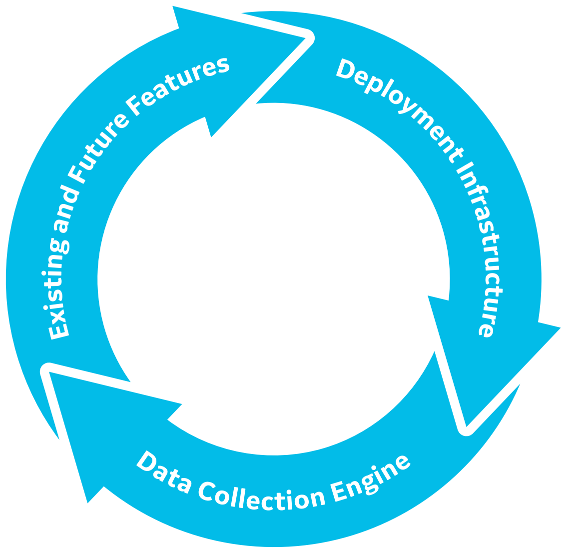


Figure 3 – Existing features provide a baseline for the Anatomical Assistant and are executed on the deployment infrastructure. The data collection engine helps to collect data that is used to develop future features and so on.

Summary

In combination with the next-generation imaging capabilities of the cSound Architecture, the A to A digital platform uniquely harnesses the power of key technological advancements to enable confident diagnosis, provide comprehensive tools, and support concise workflow. While App Assistant, Data Assistant and Anatomical Assistant all provide distinct value today, the next-generation A to A digital platform facilitates ultrasound advancement for tomorrow and beyond.

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