White Paper

AI Visual Inference
Health Care

Expanding the Reach of Breast Cancer Screening with Low-Power AI-Based Ultrasound

iCare365 Technologies, Inc. (iCare365) has developed a mobile ultrasound device based on the 11th Gen Intel® Core™ Processor with integrated Intel Iris® Xᵉ graphics. The device applies deep learning algorithms to extend breast cancer screening to more women than would otherwise be possible, using its "Dr. J" AI-driven ultrasound robot radiologist, integrated with the innovative Shangyi Cloud.

"Dr. J has been playing a growingly important role in achieving the goal of 'Healthy China 2030' by implementing AI-Powered Ultrasound Breast Cancer Screening."

– Dr. Zhou, Zhenzhong, CEO, iCare365 Technologies, Inc.

Table of Contents

Breast cancer is the most common form of cancer worldwide, with more than 2.26 million new cases diagnosed per year and an overall death rate of more than 30%.[1] As with all cancers, early detection is critical, and medical screening programs play an irreplaceable role in public health. Healthy China 2030 is a breakthrough effort to ensure that the Chinese population has easier access to health care service of enhanced quality, advocating the whole society's participation in the concept of "Health for All, and All for Health." Moving from blueprint to action, it has made dramatic achievements in the early diagnosis and treatment of cancer.

In 2017, just 10 million Chinese women were screened out of 343 million who were eligible, and just 5.2% of cases in China were detected through routine screening, compared to 60% in the United States.[2] This low rate leads to a higher incidence of diagnosis in later stages, which corresponds to lower cure rates. Scaling screening resources is complicated by the limited number of ultrasound radiologists, as well as the difficulty of serving highly distributed populations with limited access to clinical facilities.

Developments in AI and machine learning promise to help address these systemic issues, enabling technology to act as a multiplier for screening capacity. iCare365 has advanced the field by developing "Dr. J," an AI screening solution that works together with radiologists to analyze ultrasound scans. Dr. J analyzes real-time video ultrasound feeds to automatically detect and label suspected breast cancer lesions and assign BI-RADS (Breast Imaging-Reporting and Data System) ratings of disease progression to assist human diagnosis.

To make the solution scalable beyond traditional clinical settings, iCare365 has developed a portable ultrasound device that extends Dr. J's reach to patients wherever they are. Dr. J is simple enough to be operated by people without prior medical or IT training. Algorithms do the heavy lifting of interpreting large numbers of scans, passing along only suspected positive images to radiologists for quality control and referral for further treatment. iCare365 also operates the Shangyi Cloud to provide protected connectivity to the portable devices, additional AI inferencing capacity and a health information cloud (HIC) for diagnosis data, other medical records and supporting functions.

The breakthrough capabilities of the Dr. J solution are made possible by a combination of hardware and software technologies to make sophisticated AI inference possible using portable devices. These include AI model optimization using the Intel Distribution of OpenVINOTM toolkit, which helps ensure high real-time throughput from the 11th Gen Intel Core processor with integrated Intel UHD graphics. The open architecture of the solution supports the goal of building capacity through device manufacture by multiple original design manufacturers (ODMs).

Low-Power Ultrasound Device to Extend Screening Anywhere

To better serve the highly distributed populations of rural China, devices must be designed to field-use specifications that assume a more rugged operating environment than that of a traditional doctor's office. A key requirement is for the equipment to be portable so it can easily be transported and used by an individual technician or nurse. It must combine small physical size, light weight and long battery life with robust computing resources for AI visual inference.

Conventional ultrasound equipment is bulky and expensive, typically built into wheeled carts that are meant for use in hospitals or clinics, making them challenging to use in the field. These devices are performance-optimized, with little or no regard for power consumption because they are always plugged in or at least in proximity to electrical receptacles. The discrete graphics solutions used in these devices tend to be particularly power-hungry, so substantial re-imagining of the design was needed to enable portable operation.

Dr. J's reference design for the portable ultrasound device is based on a tablet device with 4G/5G connectivity and a USB-connected ultrasound probe, as shown in Figure 1. The ultrasound probe acts as a transducer that emits ultrasound waves, collects the echoes off of body tissues and processes the signal in a dedicated ultrasound board on the portable device.

AI visual inference and other application workloads are handled by the 11th Gen Intel Corei7-1165G7 processor with integrated Intel Iris X^{e} graphics. Product tests show that running AI inference using the integrated GPU reduces power consumption compared to discrete graphics. In addition to the high throughput provided by this combination of technologies, the oneAPI open programming model enables code to be portable across both CPU and GPU execution resources.

Figure 1. Laptop and tablet form factors.

This architecture is a dramatic improvement on previous solutions that employed proprietary programming limited to execution on discrete GPUs. The openness of the solution also contributes to a lower system cost than conventional solutions. Shared processing between the CPU and GPU domains enables the solution to flexibly take advantage of whatever resources are available, increasing system performance to handle more demanding workloads while also reducing programming complexity.

The portable ultrasound device provides high performance per watt to improve battery life in the field. The embedded processor is designed specifically to deliver robust computer resources at high density in space- and power-constrained environments, with the energy efficiency of integrated graphics. Configurable thermal design power (TDP) enables settings to tune the device's balance between power efficiency and performance. High-level hardware specifications are given in Table 1.

Table 1. Portable ultrasound device hardware specifications.

CPU	11th Gen Intel® Core™i7-1165G7 processor
GPU	Integrated Intel Iris® X^{e} graphics
Memory	16 GB DRAM
Storage	500 GB SSD
Local Ports	4-6 USB 3.0, 1 HDMI
Connectivity	WiFi, 4G/5G

Dr. J and the Algorithm-Assisted Future of Healthcare

The Dr. J solution incorporates visual AI models to help detect and classify breast cancer lesions, as shown in Figure 2, which are trained using hundreds of thousands of breast ultrasound images. The system uses those models to provide real-time video image analysis of ultrasound video streams, conducted on the portable device with additional inference capacity provided by Shangyi Cloud. When abnormalities are detected, Dr. J classifies them as malignant or benign lesions, cysts or lymph nodes. After screening, the system also assigns a BI-RADS (Breast Imaging Reporting and Data System) rating as a standardized way of characterizing the breast health of individual cases.

Machine-generated positive results are automatically referred to human experts for quality control, diagnosis and treatment. Notably, AI is a multiplier for the number of women a single human ultrasound radiologist is able to serve, making better use of available human resources to improve society-level outcomes. For individual providers, Dr. J enables clinical specialists to focus their effort on the patients for whom they can provide the most benefit. The Dr. J solution also provides flexibility and a clear migration path from existing solutions. Healthcare providers can incorporate existing, office-based ultrasound equipment into the same workflow as the portable devices with minimal retraining of personnel.

Breast ultrasound images are highly complex, and the lesions themselves can be quite small, making interpretation difficult and requiring a specialized skill set that may not be available in many remote settings. In addition to being technically demanding and resource-intensive, visually reviewing more than 100 scans daily is repetitive, making interpretation vulnerable to human distraction and potential misdiagnosis. Therefore, improving focus for human diagnosticians is a critical enabler for better clinical outcomes.

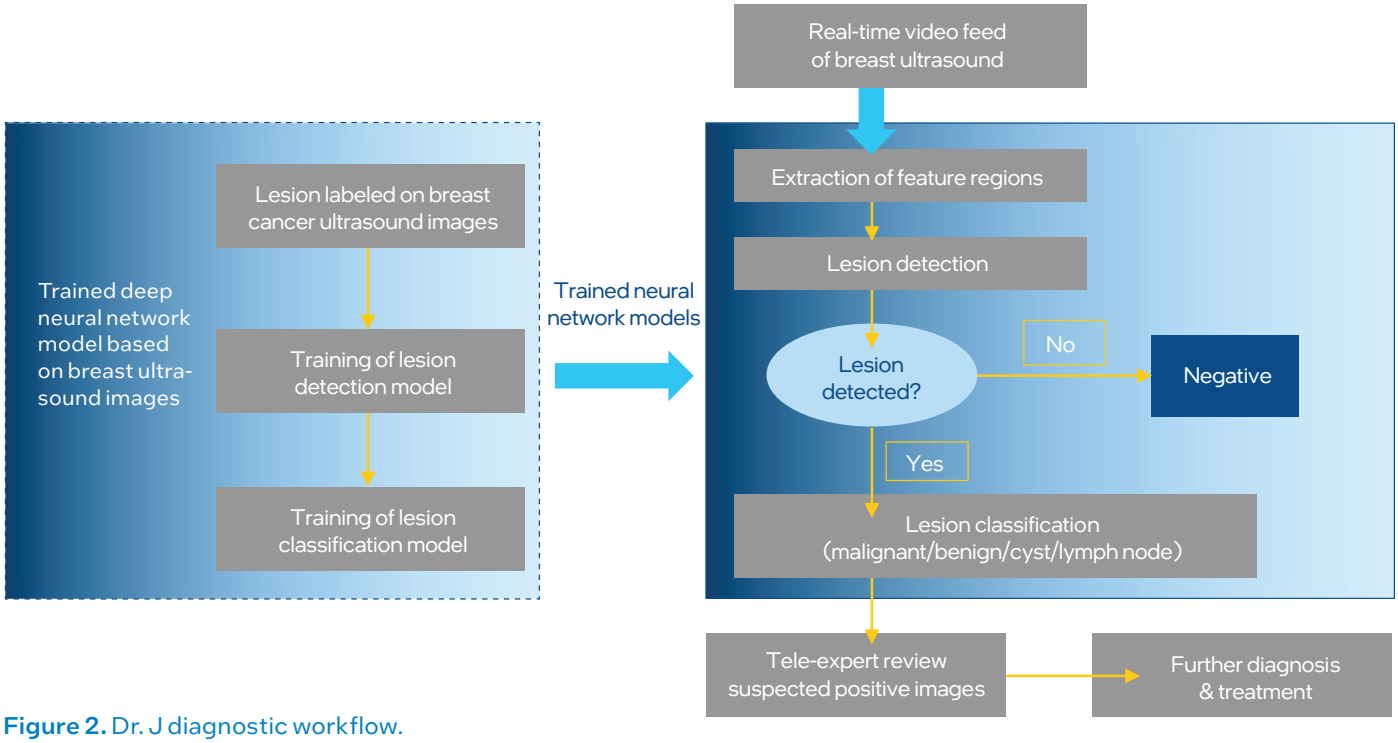

Figure 2. Dr. J diagnostic workflow.

The accuracy of results from the automated scan readings have proved to be statistically equivalent to those for human ultrasound radiologists, with sensitivity over 90% and specificity over 80%.[3] In this context, "sensitivity" refers to the ability to detect disease, avoiding false negatives that would cause cases to be overlooked. "Specificity" is the ability to accurately identify the lack of disease, avoiding false positives.

> *"Dr. J completely meets the needs of 'National Two-Cancer Screening' to resolve the shortage issue of ultrasound medical professionals. This product can play a very important role in remote mountainous areas. Nowadays in this field, there's no such machine as Dr. J that can completely replace the real work done by ultrasound professionals."*
>
> **– Wang Hongqiao, Director of Ultrasound Department of Pingdu Hospital Affiliated to Qingdao University**

The solution accelerates the rate of AI inference used for diagnosis as shown in Figure 3. Optimization using OpenVINO™ toolkit increases frame rate by over 1.9x, and integrated Intel Graphics accelerate inference by more than an additional 6x.[3] The higher volume of scans that can be analyzed using AI-based methods has the potential for increasing screening rates by orders of magnitude. iCare365 intends that more widespread screening will lead to earlier, more accurate diagnosis and higher survivability among patients. In particular, grassroots empowerment based on Dr. J helps provide equity for the presently underserved, including those in rural areas and those with limited education and financial resources.

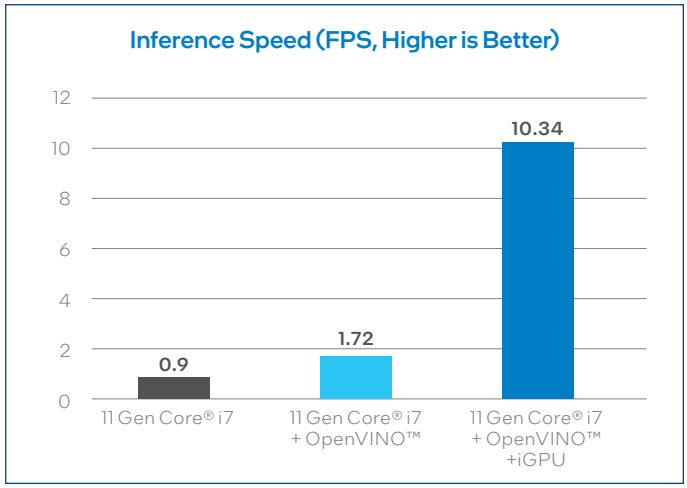

Figure 3. Accelerated AI inference.[3]

Shangyi Cloud: AI Inference Elasticity and Health Information

Just as in other industries, cloud computing offers potentially revolutionary change in the delivery of medical services. Advantages such as agility and elastic capacity are critical for the cost-effective and equitable delivery of health care, including life-saving diagnosis using portable breast ultrasound. The dramatic increases in screening capacity from the Dr. J solution that are enabled by device portability and AI-powered diagnostics benefit from both data connectivity and large-scale compute resources provided by the Shangyi Cloud.

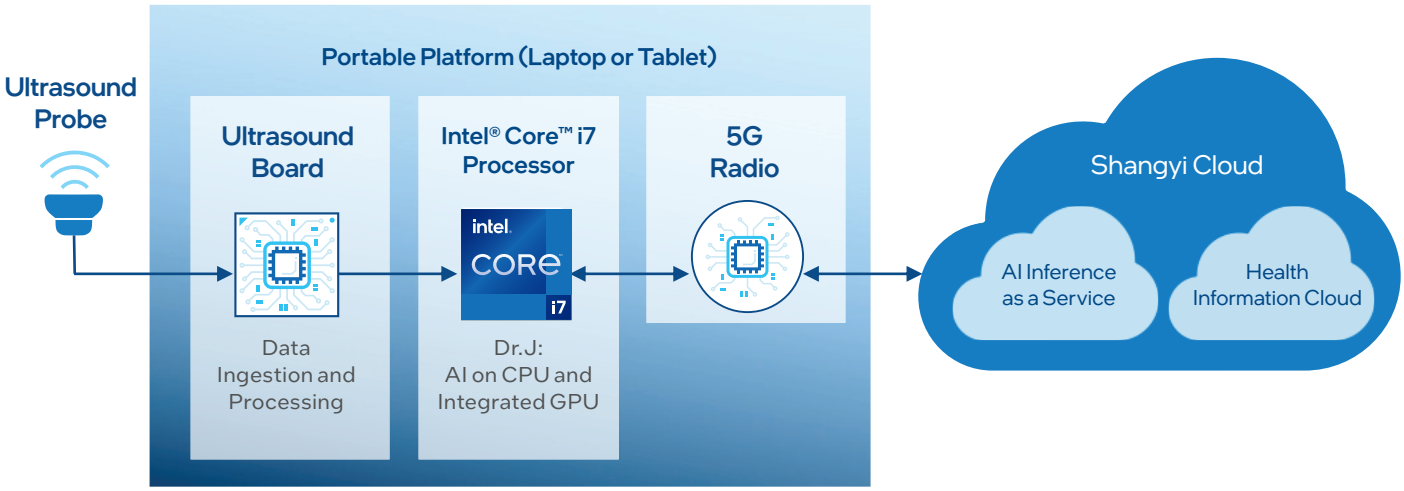

Figure 4. Shangyi Cloud connectivity to Dr. J portable ultrasound solution.

To extend the level of analysis possible for individual cases beyond what can be accomplished on a stand-alone device, the solution executes a portion of the AI visual inference remotely, through an encrypted connection to the Shangyi Cloud (typically 5G), as illustrated in Figure 4. That topology makes it possible for as many as 16 separate models to operate on ultrasound scan data simultaneously. Results are aggregated from the device and cloud, for synthesis and display on the portable device in proximity to the women being examined.

Shangyi Cloud is central to iCare365's delivery of an end-to-end solution for low-power ultrasound. Many medical practices, especially smaller regional ones, lack the resources and expertise to assemble such a specialized infrastructure from individual technology components. To reduce complexity, they often rely on commercially developed, multi-level solutions instead. By integrating the Dr. J AI-powered software with the purpose-built portable device and Shangyi Cloud, iCare365 simplifies the implementation, speeds time to production and reduces costs while serving more patients and saving lives.

The portable device utilizes the Shangyi Cloud as a massive, connected resource for screening, effectively making the system's capacity for real-time inference-based interpretation unlimited. In addition to decoupling processing and storage power from dependencies on the device itself, incorporating cloud technology enables the application of big data processing methods to ultrasound data.

A hardened cloud repository and connectivity to other systems allow deep analytics in the cloud to study outcomes, patterns and trends that contribute to the increasing quality of future approaches to diagnosis and treatment. The Shangyi Cloud health information system provides long-term, off-device protected storage for ultrasound data and interfaces with other electronic health records systems to support research and holistic care models. This dimension of the solution architecture enables better long-term social outcomes by studying real-world cases while protecting sensitive data and patient privacy.

Intel Technology Building Blocks

A combination of hardware and software technologies make it possible to meet the AI inference processing requirements of the Dr. J solution. In particular, advances in Intel architecture made it feasible to migrate Dr. J from a discrete graphics architecture to the co-processing model between CPU and integrated GPU resources on 11th Gen Intel Core processors.

11th Gen Intel Core i7 Processor

With high-performance, integrated CPU/GPU compute designed for embedded workloads, the 11th Gen Intel Core i7 processor also features hardware-accelerated AI inferencing and computer vision. The processor delivers performance needed to handle real-time interpretation of ultrasound scan data. In particular, it has the compute headroom needed to run AI visual inference and other tasks simultaneously on a single platform. It also drives up performance per watt with an energy-efficient microarchitecture based on 10-nm process technology and integrated Intel Iris X^e graphics.

AI visual inference in the Dr. J solution can take advantage of the integrated GPU's 96 graphics execution units in addition to the CPU. Advanced workload orchestration between CPU and GPU resources takes optimal advantage of the available hardware for efficient real-time performance across AI visual inference and other application tasks, with minimal latency. The processor platform benefits from Intel's extensive ecosystem enablement, which includes optimization of popular tools and deep-learning frameworks that help ensure performance and stability for the Dr. J solution.

Intel Deep Learning Boost (Intel DL Boost) accelerates the AI algorithms within the Dr. J solution. The massive numbers of calculations required for deep learning workloads are typically performed with more precision than is actually needed. Intel DL Boost accelerates the Dr. J solution by eliminating that unnecessary precision, so calculations are completed more quickly and consume less processor bandwidth. The technology also provides Vector Neural Network Instructions (VNNI), which improve throughput and cache utilization by combining three instructions into one.

In keeping with the sensitive nature of medical data, the processor incorporates a range of hardware-assisted security capabilities that help protect data. Intel AES New Instructions (Intel AES-NI) enable the system to accelerate processor-intensive portions of the AES algorithm. Intel Total Memory Encryption encrypts all data passing to and from the CPU, helping protect against hardware attacks on memory. Intel Boot Guard helps protect against compromise below the OS level, for a secure boot process.

OpenVINO Toolkit

Streamlining the optimization and deployment of deep-learning inference models on heterogeneous Intel architecture, the free, open source OpenVINO toolkit plays a critical enabling role for the Dr. J solution. OpenVINO reduces the demands that trained models place on the underlying hardware, making it possible to drive a sophisticated level of AI visual inference that otherwise could not be supported by the portable platform. That ability is a critical enabler for the vision of deploying large numbers of portable ultrasound devices to expand screening, enabling the needed functionality within a budgetary envelope appropriate for mass distribution.

The toolkit is built explicitly to be cross-platform, enabling a write-once, deploy-anywhere model so the Dr. J solution can execute AI visual inference across the CPU, integrated GPU and Shangyi Cloud. More broadly, that cross-platform architecture could also support other accelerator platforms such as Intel FPGAs with the same single code base.

OpenVINO was originally developed by Intel, and it is free to use under the Apache 2.0 license. Intel continues to maintain the toolkit to enable it for each successive platform generation. That ongoing evolution cascades to solutions that are built using the technology; OpenVINO's current enablement for future platforms, including the 12th Gen Intel Core processor, codenamed Alder Lake PS Series, helps make Dr J. future-ready.

Helping Redefine Healthcare Delivery

With more sophisticated care available and an aging worldwide population, providers must take full advantage of technology as a critical enabler for healthcare delivery. The Dr. J solution is an example of an innovative mechanism for meeting this need, especially when reaching a large, highly distributed population, as in rural China. While multiplying breast cancer screening capacity with AI-powered portable ultrasound is potentially paradigm-changing in its own right, the opportunity is significantly greater than that.

Dr. J enables AI to attain a level of accuracy equivalent to that of a professional ultrasound radiologist, with workflows that seamlessly keep human clinicians in the loop. It also balances performance, power consumption and size to provide professional screening in a highly portable device. Together, these qualities enable novel delivery strategies without compromising quality. For example, mobile screening resources could be dispatched to local sites such as community centers, and beauty salons.

Such community-centered approaches may facilitate screening individuals who may not visit doctors regularly for preventive care. Shangyi Cloud can also be a conduit to connect the point-of-care device to community and regional health centers, as well as higher-level hospitals. That model could facilitate team-based care or referrals to specialists for treatment, with cloud-resident patient data shared across the network.

iCare365 developed Dr. J as a solution to be implemented by multiple ODMs, lowering the barriers to development so that multiple providers can create products based on the technology. Looking further ahead, this technology might one day be used in connected consumer healthcare devices, providing at-home care similar to current usages such as blood-pressure cuffs and glucose meters. Another potential avenue for future solution development could include building models with software support to encompass additional healthcare usages such as analyzing other types of medical images or electrocardiograms.

Conclusion

The Dr. J solution multiplies the amount of benefit an individual caregiver can provide to society. It dramatically improves the efficiency of ultrasound radiologists by focusing their time, while at the same time, it facilitates scale by requiring only minimal training to provide critical screening. As a solution designed to be offered by multiple manufacturers, Dr. J is working to propagate an ecosystem that applies the technology for social good, to relieve suffering and protect life. As a tool for expanding the reach of healthcare, it advances iCare365's stated mission to "serve those who heal the world."

More Information

iCare365 Technologies, Inc. (iCare365):
http://www.800ai.com

11th Gen Intel® Core™ Processors:
https://www.intel.com/content/www/us/en/products/platforms/details/tiger-lake-up3.html

Intel Healthcare and Life Sciences Technology Solutions:
https://www.intel.com/content/www/us/en/healthcare-it/healthcare-overview.html

OpenVINO Toolkit:
https://docs.openvino.ai/latest/index.html

iP3 Technology:
https://www.ip3-tech.com/

[1] World Cancer Research Fund International, "Breast Cancer Statistics." https://www.wcrf.org/cancer-trends/breast-cancer-statistics/.

[2] International Journal of Advanced Computer Science and Applications, 2020. "'Dr.J:' An Artificial Intelligence Powered Ultrasonography Breast Cancer Preliminary Screening Solution." https://www.researchgate.net/publication/343361013_DrJ_An_Artificial_Intelligence_Powered_Ultrasonography_Breast_Cancer_Preliminary_Screening_Solution.

[3] Results furnished by iCare365 Technologies; not based on data measured by Intel.

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