‘Deep Learning’ Technology applied to Diagnostic Ultrasound Imaging

To meet the growing need for faster and more efficient diagnostic imaging solutions, Samsung is for the first time applying ‘Deep Learning’ technology to ultrasound imaging in breast lesion analysis. The company’s premium ultrasound RS80A system now includes ‘S-Detect for Breast,’ which employs specially developed Deep Learning algorithms.

The S-Detect for Breast module utilizes large data sets collected from numerous breast exam cases and provides the characteristics of displayed lesion as well as a suggestion as to whether a selected lesion is benign or malignant. By adopting a deep learning algorithm in the processes of lesion segmentation, analysis of characteristics and assessment, users are now provided with more accurate results with all this information being made available in a single report.

The S-Detect system has been built upon nearly 10,000 pages of data, which represent the accumulated experience and experience of the Samsung Medical center over the last 20 years.

“Samsung is moving forward in the healthcare market by not only utilizing its IT and display technology but also bringing new software solutions to ultrasound diagnosis like S-Detect,” said DongsOO Jun, President of Health & Medical Equipment Business at Samsung Electronics and CEO of Samsung Medison.

“With our leading software technology, we will continue to develop advanced imaging functions for users to experience faster and more confident diagnosis.”

“We saw a high level of conformity in the analysis and detection lesion in various cases by using the S-Detect,” said Professor Boo-Kyung Han, a radiologist at Samsung Medical Center. “Users can reduce the number of unnecessary biopsies and residents and less experienced radiologists will have more reliable support in accurately detecting malignant and suspicious lesions.”

The RS80A system is of course not intended only for breast ultrasound through its S-Detect for Breast module. Other key upgrades of the latest version (RS80A with Prestige) include:

**Enhanced Workflow and Imaging for Radiologists**

- S-Fusion — Now provides ‘Respiration Auto’ function that minimizes registration gap between real-time ultrasound and recorded CT/MRI images, which is caused by the difference in images when the patient inhales and exhales.
- CEUS+ — Applies Samsung’s ‘VesselMax’ and ‘FlowMax’ to generate clear visualization of vessels and blood flow when viewing ultrasound images with contrast agents.
- S-3D Arterial Analysis — Enables 3D imaging of vessels and provides volume measurement of artery plaque in a simplified way. Users can also track the morphological changes of the artery.

**Advanced Display Technology**

- S-Harmonic — Generates greater image conformity from near to far field while reducing signal noise based on wider bandwidths and higher frequency.
- HQ Vision — Visualizes anatomical structures with improved clarity. It helps make a reliable diagnosis especially for MSK (Musculoskeletal) imaging such as tendon and muscles.

The system uses BI-RADS scores for standardized analysis and classification of suspicious breast lesions.

For thyroid cases the RS80A system provides diagnoses based on K-TIRADS (Korean-Thyroid Imaging Reporting and Data System), the TIRADS scoring system from Dr. Gilles Russ) and the American Thyroid Association (ATA) guidelines.

Since its launch in 2014, the RS80A has been providing users with easy, fast, and accurate diagnosis around the world including in various prestigious medical institutions such as the Mayo Clinic (U.S.) and the Charité University Hospital (Germany). The latest RS80A model is now available in European and Middle Eastern markets and will launch in the Americas, China, and Russia shortly.
The clinical performance of the S-Detect system

We discussed the data currently available on the clinical performance of the S-Detect with Prof Boo-Kyung Han who is a radiologist at the Samsung Medical Center.

Q The S-Detect was developed using a database accumulated over 20 years in the Samsung Medical Center. Presumably this involved principally Korean or other Asian women. What about differences in breast characteristics between Asian and say Caucasian women, for example breast density? Does this affect the performance system?

It’s true that certain breast characteristics may differ between Asian and Caucasian women and indeed the proportion of women in Asia who have dense breasts is much greater than that say with women in the United States. However we consider that in already detected abnormal lesions, the echogenicity of the background parenchyma would have little or no effect on the morphologic characteristics of the lesions. Nevertheless we do plan to add cases from a global database to the S-Detect in near future to enhance accuracy.

Q What is the performance of the S-Detect system in validation trials, e.g. compared to experienced breast radiologists and/or histologically confirmed lesions? Regarding the feature of the system which allows the sensitivity or selectivity settings to be adjusted, in practice what is most often selected? High sensitivity mode / High accuracy mode / High specificity mode?

We are currently carrying out a retrospective comparative study in which experienced breast radiologists use S-Detect in histologically confirmed lesions. Sensitivity and specificity were found to be much better in the S-Detect system as compared to radiologists’ standard performance without the systems, especially when used in High-Sensitivity mode and High-Accuracy mode.

It is good to have the option to be able to change the sensitivity/specificity parameters but personally, I prefer high accuracy mode, because I think it is much more important to reduce the number of unnecessary biopsies for screening purposes — the use of High-Sensitivity mode could result in an increased number of unnecessary biopsies. In addition, just because US-guided biopsies are in practice easier to carry out than mammography-guided biopsies, we should nevertheless be careful not to overuse US-guided biopsy. A decision to take a biopsy due to an increased suspicion from S-Detect findings should only be taken if the suspicion of the lesion is very high, as based on the clinical condition or mammographic findings.

Q Hand-held breast ultrasound is notoriously operator-dependent. Of course, intuitively standardization would be a great advantage in this respect. How do you actually quantitate this advantage? That is exactly the challenge we are aiming to overcome. Thus, in order to alleviate the relatively higher user-dependency of ultrasound imaging in general, the S-Detect was developed to produce the best-quality static images by highly-qualified radiologists. Of course we cannot guarantee the same-level performance in every real clinical environment; the results of the multi-institutional validation study may provide information on user-dependency and help substantiate ultrasound diagnosis.

Q The new system can suggest interpretation of a suspicious lesion, a feature which looks to be of great advantage to less experienced users. What about the reaction of experienced users? Do they resent the idea that the system suggests interpretation of the image? Do they feel threatened?

We radiologists are accustomed to making decisions using real-time scanning and we evaluate a sonographic finding by integrating mammographic and US information, as well as taking into account the clinical situation. That’s one of the possible reasons why the radiologists performed less well than S-Detect in the retrospective study which was evaluated using static images. Also, S-Detect can play the role of providing a second opinion, which doctors mostly appreciate in that overall it makes decision-making more accurate.

Q One measure of the performance of the S-Detect system could be the reduction in the number of unnecessary biopsies. Do you have data on this?

The data describing the performance of the S-Detect is currently being collated and we expect publication later on this year. Information on biopsies will be included so I don’t want to anticipate the results, but for example if BI-RADS 4A masses were shown to be reliably assessed by S-Detect as being benign, then there could be a significant effect on a decreased number of unnecessary biopsies.

Q In short, what would be the overall possible clinical benefits of S-Detect?

There are many, but one example would be the use of S-Detect to help in deciding between short term follow-up or biopsy in equivocal lesions, such as in BI-RADS 4A masses.

Prof. Boo-Kyung Han is a radiologist at the Samsung Medical Center and is currently preparing a publication on the results of a multi-institutional validation study of the S-Detect module.
What exactly is “Deep Learning”? 

We wanted to find out more about Deep Learning so we spoke with Dr Yeong Kyeong Seong and Dr Moon Ho Park, who are principal engineers at Samsung and responsible for the development of the RS80A and the implementation of deep learning in the system.

Q Let’s start at the beginning. Can you give a simple description of deep learning?

Well Deep Learning is the latest rapidly developing subject in the overall field of artificial intelligence (AI). As Prof Y Bengio, from the University of Montreal, Canada, one of the world leaders in deep learning — and a consultant to Samsung in the early stages of the development of the RS80A — put it in a recent paper (Machines who learn, Scientific American Jun 2016 p41 -48), AI started as a field of serious study as far back as in the 1950s but its potential was never realized as the algorithms and computing power of the period were simply not up to the task. However in the past few years a revival of interest in AI has taken place as software patterned roughly after networks of neurons in the brain showed that the potential of AI might be realized. Deep Learning — a technique that uses complex neural networks is already reaching amazing performance levels.

With Samsung’s capabilities in computing science and display technologies, we believed we could adopt Deep Learning principles to enable fast and accurate decision-making. Samsung has an on-going commitment to innovation and this is a core element in the development of our medical equipment with the objective of making diagnoses ever more reliable and ultimately improving patient outcomes. As far as ultrasound–based medical diagnosis is concerned we concluded after evaluation of all options, that the use of Deep Learning technology was the optimal choice for better reproducibility and accuracy.

Recently there has been a lot of publicity about several applications of machine learning. For example a computer recently won a game of “Go” against expert humans. It should be noted that although the basic principles used in such applications are the same as those we use in the S-Detect for Breast, the network structures and applied algorithms are quite different.

Q In what way are your algorithms different? Were specific modifications needed to apply the principle to the recognition of lesions in ultrasound breast images?

We use customized convolutional neural networks in S-Detect for Breast. When segmenting lesions automatically from a seed point specified by a user, input images are transformed in the software to enable better recognition of various–sized lesions. This transformation involves several steps such as shifting, resizing and warping of the input images, and these transformations are included into our deep neural network as customized layers. Moreover, in order to optimize our convolutional network, some additional layers were added and modified to provide even better performance in terms of accuracy and processing time.

Q In convolutional neural networks, is it true that the software itself “learns” to improve recognition of an image without human input?

Convolutional neural networks can learn to classify an image by itself from a large amount of training data — and this is the great advantage of convolutional neural networks compared with conventional learning methods. Convolutional neural networks consist of many convolutional layers so that in each convolution layer, meaningful features can be extracted automatically from input data. These features are then integrated by going through the deep layers. A learnable classifier is added at the end of the convolutional neural network. So, instead of using hand–crafted features designed by developers, convolutional neural networks can extract optimal features from the data and make the classifier from the features at the same time during the learning process. This is precisely the reason why we adopted the convolutional neural network approach for the recognition of breast lesions.

We plan to continuously upgrade the S-Detect with more and more meaningful cases. While it is not possible for users to input such cases themselves, Samsung will regularly upgrade the software for continual machine learning. As more data accumulate, the S-Detect will yield even more accurate results.

Q How did you validate the software?

We used well-known cases whose medical diagnosis was established and whose benign/malignant status had been determined by biopsy. When evaluating the S-Detect’s practical performance, actual diagnoses of each lesion were made to make sure that the learning was processing correctly.

Q Presumably the process needs powerful computing calculation processors. Does this mean that there is a time delay while the processing is going on?

It’s true that in general, a lot of time can be needed to process deep neural networks. We knew that this drawback had to be overcome in clinical applications so a priority for us was to optimize the convolutional neural networks used in S-Detect by finding optimal input size and network structure, so streamlining the process. In this way there is absolutely no time delay for users and, what’s more to achieve the speed performance no compromises were made as regards accuracy.