ClearRead CT

The Machine Learning Revolution and Computer Aided Detection

Machine learning is on the move with high profile applications like IBM's Watson, Apple's Siri, and Google's autonomous car. The ability to accumulate and organize large data sets and leverage faster computers with greater memory capacity has taken a once niche technology to mainstream.

The goal of computer aided detection (CAD) is to detect a disease, or other condition, within a medical image, quickly and effectively so that it may be presented to a radiologist for further analysis. Although CAD has been around for some time, the rate of progress has been slow, as has other applications, such as speech recognition; however, rapid progress is now underway. The reason is simple: we now have the ability to build large complex models of perception.

Riverain's ClearRead CT is a product of this machine learning revolution, enabled by a combination of engineering know-how, advances in frameworks, and increased computational capacity.

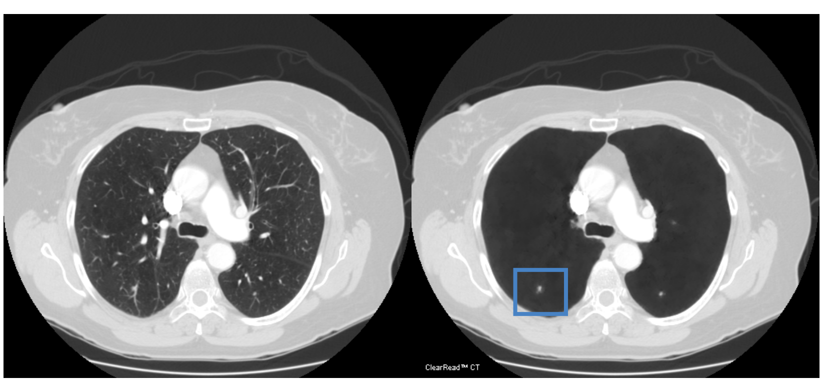
A Unique Technology for Computer Assisted Reading

Interpretation of medical images is a notoriously difficult task due to a range of issues including low disease prevalence, interfering structures, human fatigue, satisfaction of search, and distraction. As an example, identifying small, subtle, nodules in the lungs is hampered by complex vascular structures. An expert must carefully review a CT scan comprised of hundreds of slices in the presence of confounding vascular structures, to which nodules can attach. Radiologists scroll through each slice of data, using heuristics such as maximum or minimum intensity projections, however; such methods have inherent drawbacks.

Powered by machine learning and advanced modeling, Riverain's vessel suppression uses a model of the local geometry within a chest CT for robust removal of vascular structures. The technology has substantial advantages when compared to traditional approaches. Additionally, vessel suppression opens the black box by allowing the radiologist to have an unprecedented level of transparency into the CAD's decision process.

Finally, through the use of vessel suppression, subsequent analysis algorithms are far simpler. A traditional system, for example, deals with vascular attachments by thresholding and then applying post-processing. Such processes, though very common, are simply incapable of handling many scenarios, making them inherently brittle.

The figure below shows a slice from a CT volume before and after vessel suppression. As can be seen in the vessel suppressed slice at right, the nodule is cleanly "detached" from the adjacent vascular structure. The nodule is identified in the vessel suppressed slice by the blue box.



CT slice before and after vessel suppression

Building Vessel Suppression

Many challenging problems had to be solved to realize vessel suppression. There were three key challenges to address:

- Removal of the dependency on the acquisition settings
- Accumulation of sufficient data for training large complex models
- Capturing the complex entanglement of normal and diseased tissues

The third challenge is solved by a model, but in order to build the vessel suppression model, the first two challenges had to be addressed.

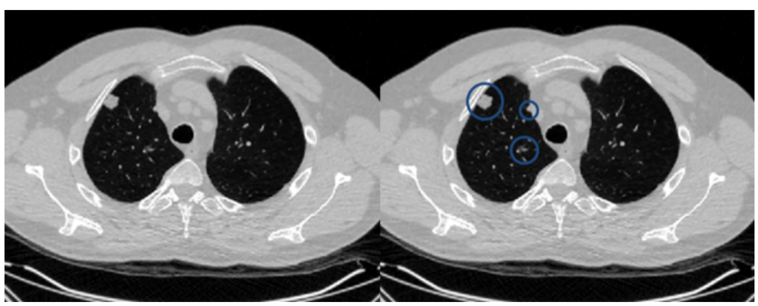
Acquisition Independence

Computer vision systems are far more sensitive to acquisition effects than radiologists. The human visual system is remarkably robust to variations in lighting and noise texture, but computer vision systems struggle.

ClearRead CT handles a broad range of acquisition protocols, a notoriously difficult problem for computer aided detection systems. Riverain utilizes adaptive algorithms so each scan is normalized for factors such as noise, reconstruction kernels, and slice thickness in a systematic fashion. This is in stark contrast to conventional approaches that collect data from different sensors to adjust component algorithms leaving them vulnerable to changes in hardware or reconstruction methods. Additionally, Riverain's adaptive approach removes limitations imposed by having software from one particular vendor, whose system was designed to operate best for one particular scanning device. This gives ClearRead CT the ability to provide enterprise imaging without compromise.

Creating Adequate Amounts of Data Through Simulation

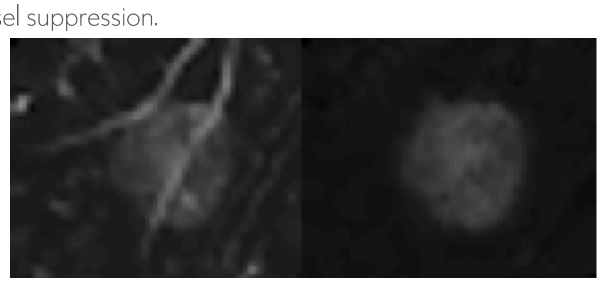
Building large complex models, such as deep neural networks, requires large training sets. Collecting large, high quality medical data sets is both time consuming and expensive, making it impractical in any realistic sense. To circumvent this problem, Riverain developed the capability to automatically create synthetic nodules, and place them into relevant anatomical contexts – such as next to the pleura wall or attached to a vessel. This was an essential capability to build vessel suppression. Vessel suppression, and other algorithms within the ClearRead CT, were built on thousands of simulated nodules. This was instrumental in building a robust, clinical solution. The figure below illustrates a slice with several simulated nodules embedded.



CT slice showing simulated nodule

Reliable Quantification and Unique Access to Clinically Important Quantities

Vessel suppression enables improved nodule detection, but its benefit continues throughout the processing chain. Suppressing vessels and surrounding structures allows for reliable segmentation of nodules, which in turn provides accurate assessment of size, and nodule characteristics in general. Vessel suppression removes vascular structure within ground glass nodules. This allows a radiologist, or analysis software, to reliably determine the relative amount of solid tissue, an extremely important aspect for clinical decision making. This is illustrated in the figure below, which shows a zoomed-in chip of a ground glass nodule with and without vessel suppression.



ClearRead CT | Vessel Suppress Chip

Deep Computation

While simplicity is often a virtue, complex problems are unlikely to be solved by simple approaches as there are just too many factors to contend with. ClearRead CT is a modern approach that utilizes the latest advances in machine learning, such as **deep learning**. ClearRead CT has surpassed the state-of-the-art by a significant margin based on a combination of frameworks, modeling, and computational ingenuity. High reliability and significant performance are achieved by utilizing substantial amounts of processing; even so, ClearRead CT system runs on commodity hardware, without the need for special computer cards (GPUs) or large memory systems.

What it Means

The performance of radiologists needs to be understood in practical terms: if it were practical for a radiologist to thoroughly interrogate each region of a medical scan, then of course their performance would be much higher. Unfortunately, due to increasing use of thin-section data and a larger patient workload, radiologists are in fact being given less time to read each study. This trend is not sustainable – radiologists need better tools. ClearRead CT is a tool designed to not only improve accuracy, but perhaps more importantly, the efficiency of radiologists.

In much the same way current computer chess programs do not play chess like people, computer vision systems that read medical images will not read like a radiologist. Clinicians utilize abstract knowledge in the form of anatomy and physiology when performing medical interpretation tasks, but use of such knowledge is something that remains elusive for computers. Tools such as ClearRead CT aim to aid in the more arduous tasks of medical interpretation, including systematic, thorough investigation of each voxel so that radiologists can focus on actual clinical decision making and improving the lives of their patients.

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