Microcalcification detection with and without prototype CAD system (LIBCAD): a comparative study

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Purpose

Breast cancer is the most common cancer all over the world. Early detection of cancer, in either diagnosis or screening programs, decreases the mortality rates. The survival rate is greatly influenced by how early the cancer is treated, thus it is important to discover the disease at an early stage. Clusters of microcalcifications are early sign of possibly cancer and are in general not palpable. Computer Aided Detection (CAD) is software that aids radiologists in detecting microcalcifications.

Developing a CAD system that is affordable to all laboratories, and individual radiologists on their desktops, is of great value to the field for early detection of breast cancer. LIBCAD [22] is CAD software that is recently developed, in the form of Dynamic Linked Library (DLL), to be affordable for all image viewers that do not support detection capabilities. In the present article we measure the performance of microcalcifications detection of this new software and compare it to the performance of an experienced radiologist.
Methods and Materials

I. Working team & Data Collection:

The working team comprises a multidisciplinary group of several backgrounds including statistics, computer science, and engineering, along with a trained, experienced and professional radiologist (10 years’ experience, 6000 mammogram / year).

Mammograms are collected from two different institutions. All images are acquired from digital mammography. The radiologist reads the digital mammograms and then marks the lesions in the images. The marked lesions are also tagged according to the different radiological lexicons and then categorized by the radiologist according to the "Breast Imaging Reporting and Data System" (BIRADS) scoring system. Table 1 is the description of the international BIRADS scoring system for diagnosis of breast lesions. We have implemented our protocol for reading and marking by designing software that facilitates the radiologist with labelling, marking, and attributing tools. Figure 1 is a snapshot of this software. All lesions were classified according to the BIRADS system, then a BIRADS score was assigned for each image [10]. All suspicious lesions classified as BIRADS 3, 4 and 5 are pathologically proven after core and vacuum needle biopsy.

Category 0 mammographic assessment is incomplete

Category 1 negative

Category 2 benign finding(s)

Category 3 probably benign finding(s)

Category 4 suspicious abnormality

Category 5 highly suggestive of malignancy

Table 1: "BREAST IMAGING REPORTING AND DATA SYSTEM" (BIRADS) SCORING.

II. Microcalcification Detection in LIBCAD

Image pre-processing is essential; it normalizes data for a particular method. One worth mentioning fact is that digital mammograms (as those used in our project) greatly abandon many pre-processing steps. It is evident that those unpleasing artefacts, marks, and image noise in the analogue image have no existence in the digital mammogram; this resulted in a much cleaner image.
After noise removal breast region is extracted from the image; this step is called segmentation. Then, the image is normalized to make sure that images from different mammography machines lay on the same scale. The final two steps are detecting the microcalcifications foci, and then grouping those foci to different clusters. The radiologist can opt to view only dense clusters by manipulating a threshold level. Figure 2 is a demonstration of the CAD detection of microcalcifications after applying different threshold levels.

The CAD detects and marks microcalcifications foci, even if those foci that are not clustered. To measure the accuracy of the algorithm, we define a cluster as follows. It is a set of detected foci, where any two of them are at most 3 mm apart. If the number of foci per cluster is lower than the selected threshold level, the cluster is considered undetected although those foci will be marked to the radiologist. A cluster is considered a Positive cluster, and hence is counted, if the number of its detected foci are larger than the selected threshold level and its centre is located within the true marking (ground truth) of the radiologist proven by a biopsy.

III. LIBCAD as a Dynamic Linked Library (DLL)

LIBCAD is deployed in the form of Dynamic Linked Library (DLL), which is a set of computer functionalities (library) that can be embedded to any other computer software, in general, or image viewer, in particular. This allows the developers of any image viewer, which does not provide CAD capabilities, to import this library to their viewer. The main objective of that form of deployment is to make the product affordable to as many radiology centres as possible.
Fig. 1: A snapshot for a software used by the consultant radiologist to mark every lesion in a mammogram. The radiologist marks accurately the outline of a lesion with entering all related information, e.g., BIRAD and histological results

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Fig. 2: Microcalcification detection using different threshold levels. (A) Digital mammography MLO view showing clustered microcalcification. (B) Microcalcification at high aggressive threshold level. (C) Microcalcification at moderately aggressive threshold level. (D) Microcalcification at low aggressive threshold level.

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Results

Before discussing the results, an important remark on the measure of accuracy is in order. We explained above the criterion of counting a cluster as a True Positive (TP) cluster. If an image contains more than one clustered microcalcifications, and at least one of them is detected by the algorithm we consider the image a TP (Figures 4 & 5). On the other hand, the algorithm may detect scattered foci on a normal image, and they do not cluster in the sense of the definition provided above; hence this image is considered True Negative (TN); see Figure 3. If the CAD detects some foci in a cluster but they neither fulfil the closure criterion of 3 mm, defined above, nor exceed the selected threshold value they will be marked to the radiologist; however the image will be counted as a False Negative (FN).

<table>
<thead>
<tr>
<th></th>
<th>Microcalcifications (Total)</th>
<th>Microcalcifications (alone)</th>
<th>Microcalcifications (with mass)</th>
<th>False Marks / Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiologist detection</td>
<td>100% (38/38)</td>
<td>86.8% (33/38)</td>
<td>13.2% (5/38)</td>
<td>0</td>
</tr>
<tr>
<td>CAD Detection at low threshold (aggressive)</td>
<td>97.4% (37/38)</td>
<td>86.8% (33/38)</td>
<td>10.6% (4/38)</td>
<td>0.25</td>
</tr>
<tr>
<td>CAD Detection at high threshold (less aggressive)</td>
<td>92.1% (35/38)</td>
<td>84.2% (32/38)</td>
<td>7.9% (3/38)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 2: Comparison between the experienced radiologist and CAD detections of Microcalcifications at aggressive threshold:

All the results are presented in Table 2, and explained as follows. Malignant microcalcifications were detected by the radiologist in 100% (38/38) of cases: 86.8% (33/38) microcalcifications alone and 13.2% (5/38) microcalcifications with masses. This is compared to 97.4% (37/38) of cases: 86.8% (33/38) and 10.6% (4/38), respectively, detected by LIBCAD at the aggressive threshold of 4 foci per cluster. When the threshold is set at 8 foci per cluster (a less aggressive threshold) LIBCAD detects 92.1% (35/38) of cases: 84.2% (32/38) Microcalcifications alone, and 7.9% (3/38) Microcalcifications
with masses. This means when lowering the threshold, the sensitivity increases at the expenses of increasing the FPs. As mentioned above, some cases are counted as FN because they do not fulfil the criterion of clustering, as defined above, although the CAD detected and obviously marked many foci in the cluster (Figure 8). Therefore, the reported performance is conservative. Only two cases are counted as FN for that the CAD was not able to detect their foci—one amorphous low density calcification alone and the other one was calcifications in a dense mass masked by the density of the mass and both were malignant cases (Figure 7). However, the CAD was very successful in detecting a faint cluster of microcalcifications in a very dense breast (Figure 6).
Images for this section:

**Fig. 3:** (A): Digital mammography MLO view showing no microcalcification (B): Microcalcification was not detected by CAD, a true negative result

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**Fig. 4:** (A) Digital mammography MLO view showing clustered microcalcification. (B): Microcalcification detected by CAD. True positive finding.

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**Fig. 5:** (A) Digital mammography MLO view showing clustered microcalcification as well as atheromatous vascular calcifications. (B): both are detected by CAD. True positive finding.

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**Fig. 6:** (A) Digital mammography MLO view showing clustered amorphous microcalcification (blue boundary) in association with a dense mass lesion. (B) The microcalcification was not detected by CAD (blue boundary), False negative result.

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Fig. 7: (A) Digital mammography MLO view showing clustered microcalcifications (blue boundary) (B) The microcalcifications were detected (blue boundary); however they are far from each other and hence counted as False Negative.

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Fig. 8: (A) Digital mammography MLO view showing clustered microcalcifications (blue boundary). (B) The microcalcifications were detected by CAD (blue boundary); however, their number is less than a chosen threshold and hence the image is counted as a False Negative.

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Conclusion

DISCUSSION

The present article presents the first study on the first commercial version of LIBCAD. A previous study [11] reported very technical information, on the performance of mass detection, suitable for Engineering community. A comparative study, similar to the present one, for comparing the performance of mass detection to radiologist's readings is in preparation. This is in addition to a clinical trial to compare the readings of the radiologists with/without LIBCAD, and the effect on the recall rate.

Meanwhile, In [12], the authors compare the performance of Versions 3.1 and 8.3 of a commercial CAD software system (ImageChecker, R2 Technology [13]), by Hologic, Inc. Microcalcifications were detected at the rate of 100% for both versions at FP marks per image of 0.15 and 0.13, respectively. Another study [14], measured the performance of Version 3.2 of the same CAD for detecting only amorphous microcalcifications. They reported 51% sensitivity at 0.5 FP marks per image-(what was reported is 2.0 FP marks per case, which is approximately equivalent to 0.5 FP marks per image for cases with 4 views per case).

These numbers are comparable to the performance of LIBCAD, reported in the present article, of 97.4% at 0.25 FP marks per image. If we exclude the case that contains amorphous microcalcifications from the calculations, the sensitivity would by 100% instead of 97.4% at 0.25 FP marks per image. The present study needs to be followed by another study that is rich of cases having amorphous microcalcifications and cases having microcalcifications in association with dense masses, to measure the performance on these two subtle signs.

It is worth mentioning that LIBCAD marks the individual foci, as opposed to marking the whole cluster with a single mark. Then, the radiologist can manipulate a threshold value to display only those clusters that are dense with microcalcifications. This marking procedure may be of interest to some radiologists, as they will be able to view all foci across the image even if these foci do not cluster together.

In Section 2, above, we mentioned that LIBCAD is deployed in the form of a Dynamic Linked Library (DLL)-a form of computer software-that makes it importable to any other software, in particular image viewers. This feature may serve many radiologists who already use their image viewers, which do not provide CAD capabilities. In addition, this feature may serve researchers and scientific communities who run experiments and write computer software for that purpose.
CONCLUSION

We conducted a comparative study between the readings of an experienced radiologist and the performance of a new CAD (LIBCAD). We collected digital mammograms from two institutions, and implemented a protocol for reading, marking, and labelling images. The CAD system proved to be a good tool for detecting microcalcifications giving comparable results to the experienced radiologist. The CAD compares, as well, to some commercial CAD systems existing in the market whose performance is reported in the literature. Other manuscripts are in preparation to report the performance of the CAD for mass detection.
References

REFERENCES


Personal Information

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