AN AUTOMATIC MACHINE LEARNING SYSTEM FOR CORONARY CALCIUM SCORING IN CLINICAL NON-CONTRAST ENHANCED, ECG-TRIGGERED CARDIAC CT

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Abstract
Presence of coronary artery calcium (CAC) is a strong and independent predictor of cardiovascular events. We present a machine learning system using estimated positions of the coronary arteries to automatically identify and quantify CAC in routinely acquired cardiac non-contrast enhanced CT. Candidate lesions the system could not label with high certainty were automatically identified and presented to an expert. This allowed a substantial increase in performance with little expert effort.

Purpose

The purpose of this work is to automatically identify and quantify calcified atherosclerotic plaque in coronary arteries in non-contrast enhanced ECG-triggered cardiac CT.

Data

- Cardiac CT scans
- No contrast-enhancement
- ECG-triggering
- Resolution: 0.29-0.49 mm in-plane, 3 mm thick sections
- 200 scans with manually annotated calcifications
- 36 exclusions due to metal implants and stents

Results

Identified coronary artery calcium was quantified with the clinically used Agatston score. Spearman's ρ between reference and automatically determined Agatston scores was 0.94 (Figure 2).

Accuracy of patient assignment to a cardiovascular risk category based on Agatston scores (I: 0, II: 1-10, III: 11-100, IV: 101-400, V: >400) was 0.86 (Table a).

Figure 3 shows examples of candidates selected for review. Review of on average 1.8 selected candidates per image corrected 40% of errors and increased Spearman's ρ to 0.98 and risk categorization accuracy to 0.92 (Table b). In 41% of patients, no candidates were selected for review. In these patients, risk categorization accuracy was 96%.

a)

Automatic \ Reference	I	II	III	IV	V
I	63	4	0	0	0
II	3	5	1	0	0
III	5	2	29	3	0
IV	1	0	1	25	2
V	0	0	0	1	19

b)

Automatic \ Reference	I	II	III	IV	V
I	69	5	0	0	0
II	3	6	1	0	0
III	0	0	29	1	0
IV	1	0	1	27	1
V	0	0	0	1	20

Methods

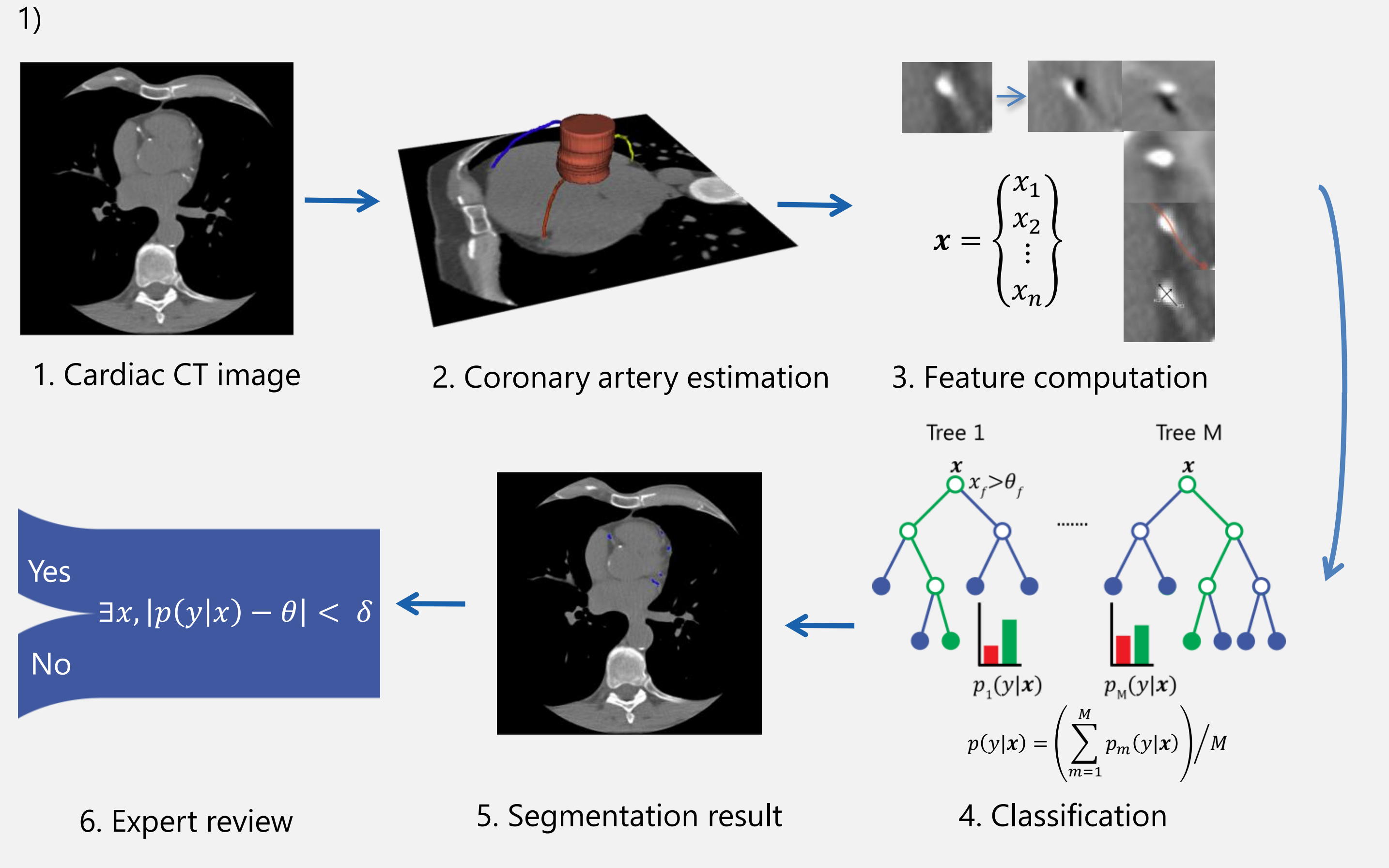
A machine learning approach was used to distinguish between coronary calcifications and other high-intensity objects (Figure 1). Clusters of connected voxels above a clinically used intensity threshold of 130 HU were considered candidate calcifications.

Candidates were described by shape, intensity and spatial features. Shape features were computed using a PCA of the candidate. Up to second order Gaussian derivatives at five scales were used as intensity features, along with maximum and average intensity. Spatial features were based on the estimated position of the coronaries.

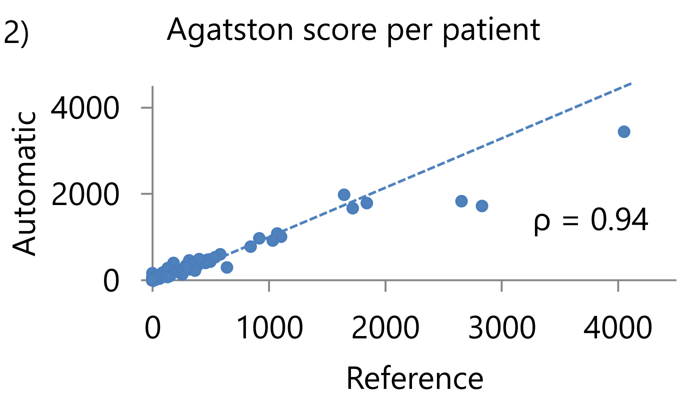
The position of the three major coronary arteries (LAD, LCX and RCA) was estimated through multi-atlas based registration with iterative atlas selection based on the SIMPLE algorithm (Langerak et al., *IEEE TMI* 29(12): 2000-2008 (2010)).

Candidates were classified using a forest of extremely randomized decision trees (Geurts et al., *Mach Learn* 63(1): 3-42 (2006)). Candidates whose posterior probability $p(y|\boldsymbol{x})$ was within a margin δ from the classification threshold θ were selected and presented to an expert reviewer for further inspection.

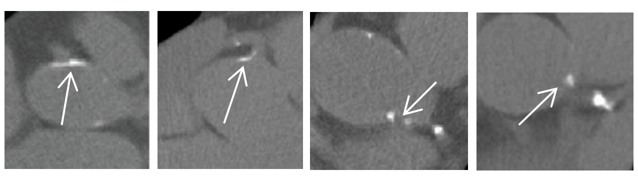
1)



2)



3)



Conclusions

- The proposed system can automatically identify and quantify calcified coronary plaque in non-contrast enhanced ECG-triggered cardiac CT
- The system is able to effectively select difficult examinations for refinement by an expert.

Acknowledgements

This work has been financially supported by PIE Medical Imaging B.V.

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