Low-cost healthcare solutions for tuberculosis screening and pregnancy risk prediction using X-ray, ultrasound and deep learning

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Bram van Ginneken
Diagnostic Image Analysis Group, Radboud University Medical Center; Fraunhofer MEVIS, Bremen; Thirona, Nijmegen
Disclosures

- Developer CAD4TB (Delft Imaging): royalties & funding
- Co-founder and CSO Thirona: stock, royalties & funding
- Developer Veolity (MeVis Medical Solutions) & DynaCAD Lung (InVivo): royalties & funding
- ScreenPoint is a spin-off from DIAG; DIAG receives royalties & funding
- DIAG funding: Canon, Siemens Healthineers, Philips Medical, Elekta, Sectra, Novartis
Tuberculosis: 4500 deaths per day
**Tuberculosis**
- Bacterial infection
- Diagnosed by RT-PCR
- PCR test is expensive and time consuming and not always available
- \(~4500\) deaths/day
- Kills old, very young and the working population
- Affects mainly poor countries/regions
- No vaccine (despite decades of effort)
- Cheap and effective cure (\$10)
- X-ray imaging can screen quickly

**COVID-19**
- Viral infection
- Diagnosed by RT-PCR
- PCR test is expensive and time consuming and not always available
- \(~4500\) deaths/day currently
- Kills almost exclusively the old and very old population
- Affects the whole world
- No vaccine yet
- No cure
- X-ray imaging, CT and blood tests can screen quickly
Triaging with chest x-ray
Segmentation with Active Shape Models
Texture feature extraction

For each region of interest, a histogram of the response to each filter is computed. Moments of each histogram (standard deviation, skew, kurtosis) are texture features.
Result for TB screening database

ROC curve for best performing feature set ($A_z=0.820$).
Detection of tuberculosis
Input: image. Output: number(s). Classifier/discriminator

LeNet (1998)  
AlexNet (2012)  
VGGNet (2013)

Inception v3 (2015)  
DenseNet (2016)  
Artificial intelligence for the detection of tuberculosis

- CE certified
- 40+ publications
- Activated in 30+ countries
- Screened over 300,000 people
Computer aided detection of tuberculosis on chest radiographs: An evaluation of the CAD4TB v6 system

Keelin Murphy¹, Shifa Salman Habib³, Syed Mohammad Asad Zaidi³, Saira Khowaja¹,⁴, Aamir Khan⁵, Jaime Melendez³, Ernst T. Scholten¹, Farhan Amad⁶, Steven Schalekamp¹, Maurits Verhagen⁵, Rick H. H. M. Philipsen¹, Annet Meijers⁵, and Bram van Ginneken¹

Each observer (and CAD4TB v6.0) vs reference standard of remaining 4 observers

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**Sensitivity**

0.0 0.2 0.4 0.6 0.8 1.0

0.0 0.2 0.4 0.6 0.8 1.0

**1-Specificity**

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Keevin Murphy, Henk Smits, Arnoud J.G. Knoops, Mike B.J.M. Korst, Tijjs Samson, Ernst T. Scholten, Steven Schalekamp, Cornelia M. Schaefler-Prokop, Rick H. H. M. Philippsen, Annet Meijers, Jaime Melendez, Bram van Ginneken, Matthieu Rutten

Author Affiliations

- Address correspondence to: (email: keelin.murphy@radboudumc.nl)

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CAD4COVID-xray

• Started with pretrained CAD4TB
• Finetuned on pneumonia data
• Finetuned on COVID-19 x-rays from one Dutch hospital
• Test on data from a second Dutch hospital

• Observer study with 6 radiologists
• They scored each image as:
  • (0) Normal: No finding
  • (1) Abnormal but no lung opacity consistent with pneumonia
  • (2) Lung Opacity consistent with pneumonia (unlikely COVID-19)
  • (3) Lung Opacity consistent with pneumonia (consistent with COVID-19)
Fondation Botnar champions the use of AI and digital technology to improve the health and wellbeing of children and young people in growing urban environments around the world. We do this by supporting research, catalysing diverse partners, and investing in scalable solutions.
As the use of AI and data science improves the health and well-being of young people in our region, we advocate for ongoing research, development, and investing in the future.
Infection prevention and control measures

Fever (history or >37.5°C) or Cough

X-ray CAD4COVID
X-ray CAD4TB
Pulse oximetry SpO₂
RDT COVID-19

A or D
A or D & C
A or D & B ± C
B ± C
None

Presumptive COVID-19 case non-severe
Presumptive COVID-19 case severe
Presumptive COVID-19 and TB case
Presumptive TB case
Other cause of illness

Self-quarantine or isolation depending on age and underlying conditions
Confirmatory COVID test and admission to specialised ward for care
Confirmatory TB & COVID tests; transfer to infectious disease unit for care
Transfer to NTP, confirmatory TB test and management according to guidelines
Consider RDTs on other febrile illnesses and transfer to outpatient clinic

COVID-19 & TB triage algorithm for low-income countries with community transmission.
Klaus Reither, Swiss Tropical and Public Health Institute, Mistral Study funded by Botnar Foundation
800 maternal deaths per day, 99% in low resource countries

Maternal Mortality Ratio, 2015
The maternal mortality ratio is the number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births.

Source: Gapminder (2010) and World Bank (2015)
OurWorldInData.org/maternal-mortality • CC BY
Low-cost ultrasound devices
BabyChecker: current features

Gestational age  Twins  Breech position
Automatic measurements are possible
But how to acquire the right frame?
Sweep protocol

K.K. DeStigter et al., Low-cost teleradiology for rural ultrasound, GHTC (2011)
Sweep 8

Head
Head partly
Body
Side view
Transducer detached
Other
Automatic detection of pregnancy risks

- Head
- Head partly
- Body
- Sideview
- Transducer detached
- Other
Automatic detection of pregnancy risks

Head
Head partly
Body
Sideview
Transducer detached
Other
Automatic detection of pregnancy risks
Estimation of gestational age from sweep frames

Comparing GA obtained from HC

GA estimated from HC obtained utilizing the OSP [weeks]

Reference GA estimated from HC obtained in the standard plane [weeks]

- Identity line
- Hadlock 16% and 84%
- Hadlock 2.5% and 97.5%
- Micrls OSP N=225

Original Contribution

AUTOMATED FETAL HEAD DETECTION AND CIRCUMFERENCE ESTIMATION FROM FREE-HAND ULTRASOUND SWEEPS USING DEEP LEARNING IN RESOURCES-LIMITED COUNTRIES

THOMAS L.A. VAN DEN HEUVEL,*,† HEZKIEL PETROS,‡ STEFANO SANTINI,‡
CHRIS L. DE KORTE,§,† AND BRAM VAN GINNEKEN*"
Current status of the BabyChecker

• All deep learning networks running real-time on Android phone
• Real-time feedback during acquisition of the sweeps
• Segmentation of placenta for detection of placenta previa
• Investigating adjustment of the sweep protocol
• Planned release 2021
Two examples of low-cost healthcare solutions

• Countries with limited resources are open to use of AI

• Deep learning made rapid development of these applications possible
  • They do not run on an expensive GPU
  • They do not require millions of example images