OtoScan: A Novel, Inexpensive System for Comprehensive Diagnosis of Middle Ear Infections With an Intelligent Mobile Otoscope

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Otitis media (OM) is the leading cause of hearing loss in children globally, affecting nearly a billion people per year. Impoverished areas typically lack trained ear specialists, which prevents millions from being diagnosed and treated while causing severe complications such as fatal inflammation. Currently, there is no viable diagnostic system for inexpensively and accurately detecting such ear conditions. This research presents OtoScan, a revolutionary pipeline for the detection of middle ear infections using novel ensemble networks for diagnosis and a custom 3D-printed mobile otoscope. The physical attachment was developed using custom-designed 3D models, a compact magnification lens, fiber optics, and various electronics for illumination. To develop detection algorithms, public otoscopic images were collected and augmented with realistic perturbations. An ensemble of the InceptionV3, InceptionResNetV2, and Xception architectures trained using transfer learning and label smoothing was developed to mitigate class imbalance and overconfidence while improving diagnostic accuracy for acute and chronic suppurative OM. Regions of interest are highlighted as gradient saliency maps in a smartphone application using Grad-CAM++. Evaluation on public images shows that the proposed algorithm greatly surpasses standard and state-of-the-art architectures such as a pretrained ResNet-50 in accuracy and F1 score. Further testing using an industry-standard otoscopic simulator validated the real-world viability of this system. With a production cost of $9.50 USD (>10 times cheaper than standard otoscopes), OtoScan has the potential to democratize ear care and drastically improve patient outcomes through early screening and monitoring in developing regions.

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