Analysing open-source images with crowds of people to assess face mask usage for epidemiological studies

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Background: Face masks are an available intervention for emerging respiratory infectious diseases. Assessing face mask usage at a large scale is essential in many epidemiological studies but difficult to achieve. We aimed to develop and examine an innovative solution with artificial intelligence (AI) techniques to enable the assessment by analyzing open-source images with crowds of people.

Methods: We created a new mask-related database for the development. The solution included four analysis stages: 1) detecting all face images for a given crowd image, 2) excluding unusable face images (Unusable, very blurry or largely occluded), 3) classifying the remaining images into Mask-Yes or Mask-No, and 4) classifying the environment (Indoor or Outdoor). We employed state-of-the-art AI techniques for Stages 1 and 4, and finetuned large pre-trained machine learning models for Stages 2 and 3. Finally, we evaluated the solution using ten randomly selected open-source images with at least 30 people in each.

Results: In the evaluation with the ten crowd images, the developed platform reported 1509 individual face images in total, including Unusable (n=710), Mask-Yes (n=431) and Mask-No (n=368). In the mask usage reports of the ten crowd images, we found that the absolute errors (reported usage % – manually corrected usage %) ranged from -5.2% to +2.3%. The reports of the outdoor (n=7) or indoor (n=3) environment were all correct (10 out of 10, 100%).

Conclusion: The innovative AI solution potentially enables timely assessment of face mask usage at a large or even global scale for epidemiological studies.

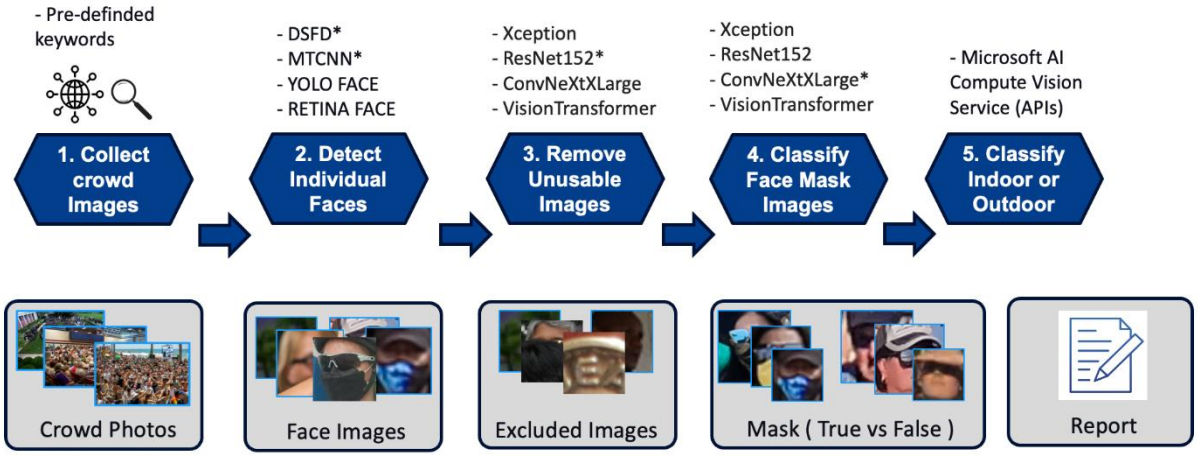


Figure 1. The five essential image analysis stages in the innovative AI system proposed to analyse face mask usages from open-source images for epidemiological studies. Different machine learning models were evaluated at Stages 2, 3 and 4. "" denotes the ML models selected through the study.*

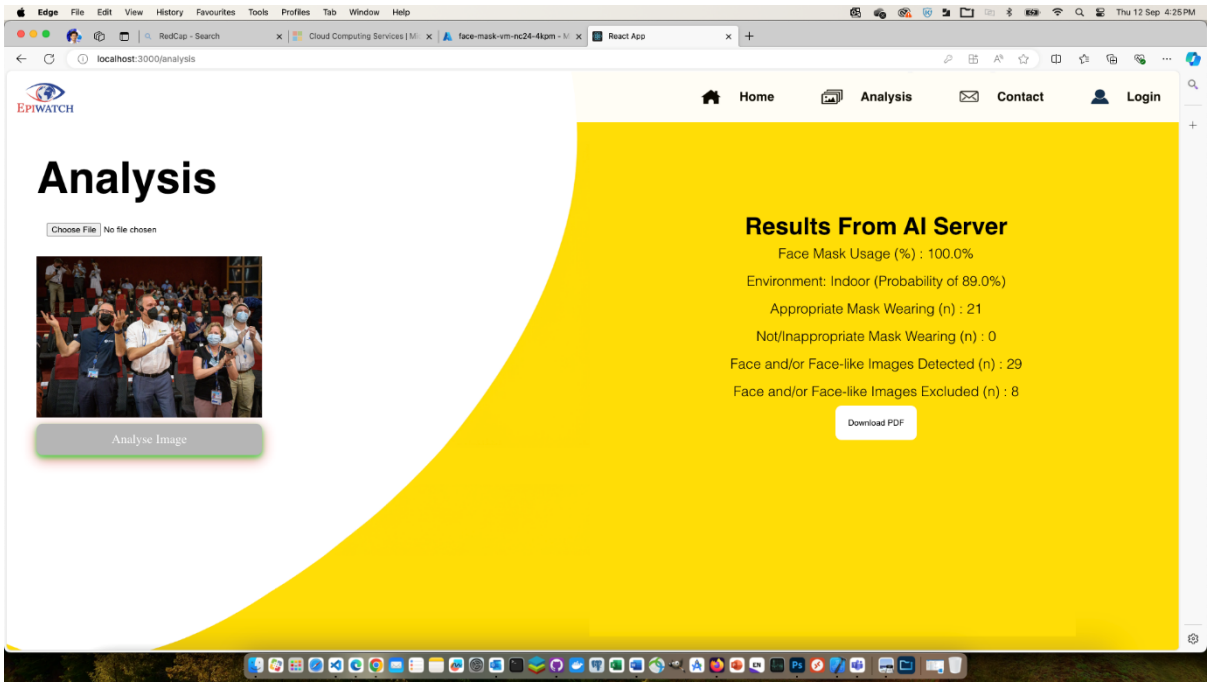


Figure 2. A screenshot of the web application developed to assess face mask usage from a given open-source image with a crowd of people.

Table 2. The precision, recall and F1-Score in testing the finetuned machine learning models selected to exclude unusable face images and classify the wearing of face mask (Mask-Yes, Mask-No).

Class	**Measure**	**Xception (23M)**	**ResNet152 (58M)**	**ConvNeXt Large (196M)**	**ViT Large (306M)**
Face Mask Yes vs No	Precision	0.754	0.975	0.972	0.988
	Recall	0.973	0.988	0.983	0.976
	F1-Score	0.867	0.982	0.986	0.982
Unusable Vs Usable	Precision	0.833	0.921	0.903	0.915
	Recall	0.557	0.932	0.953	0.930
	F1-Score	0.699	0.926	0.928	0.921

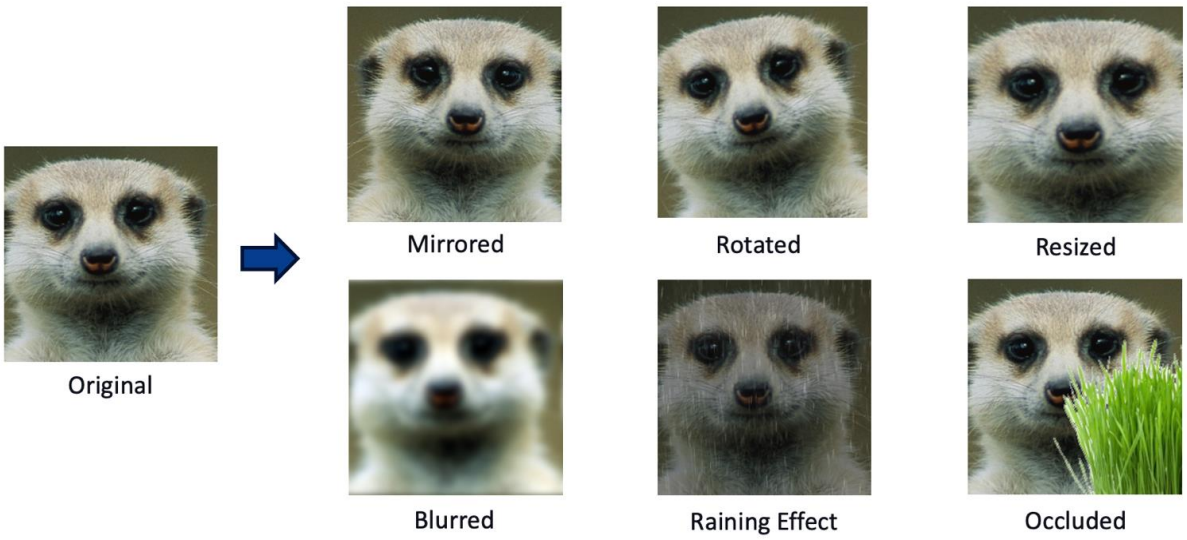
*Table 3. Evaluation of AI innovation using 10 open-source images with results from automated calculations (Cal) and manual corrections (Corr). *: Denotes the error range from -5.2% to 2.3% in the evaluation.*

Case	**Unusable (n)**	**Mask-Yes Vs No (n)**	**Face Mask Usage (%)**		**Environment**
	Reported (Error)	Reported (Error)	Reported (Corrected)	Absolute Error	Reported (Confidence %)
1	67 (6)	4 vs 32 (1)	11.1 (8.8)	+2.3*	Outdoor (93.5)
2	5 (2)	40 vs 0 (0)	100.0 (100.0)	0.0	Indoor (68.7)
3	326 (12)	122 vs 105 (5)	53.7 (53.2)	+0.5	Outdoor (53.7)
4	54 (5)	4 vs 66 (0)	5.7 (4.2)	+1.5	Outdoor (99.7)
5	8 (0)	21 vs 0 (0)	100.0 (100.0)	0.0	Indoor (89.0)
6	44 (5)	95 vs 13 (1)	88.0 (99.7)	-1.3	Outdoor (99.4)
7	10 (1)	38 vs 2 (0)	95.0 (95.1)	-0.1	Indoor (63.7)
8	41 (9)	27 vs 14 (2)	65.9 (71.1)	-5.2*	Outdoor (98.4)
9	73 (12)	75 vs 9 (1)	89.3 (87.5)	+1.8	Outdoor (99.7)
10	82 (7)	3 vs 129 (2)	2.3 (1.5)	+0.8	Outdoor (79.2)
Sum	710 (59)	431 vs 368 (12)	-	-	-

Appendix 1: The search engines and websites approved for the data collection.

Index	Search Website	CC License status or Filter/Rules Applied
1	https://commons.wikimedia.org/	Entire website with a CC license.
2	https://pxhere.com/	Entire website with a CC license.
3	https://unsplash.com	Entire website with a CC license.
4	https://search.creativecommons.org/	Filter: CC licenses
5	https://www.flickr.com/	Filter: “All creative commons”
6	Microsoft Bing Image	Filter: “Creative Commons licenses”
7	Google Image	Filter: “Creative Commons licenses”
8	https://openverse.org/	Filter: CC licenses
9	https://www.pexels.com/	“All images … on Pexels are free to use”.

Appendix 2: Selected examples to illustrate augmentation methods, applied in the random over-sampling process to create balanced datasets for finetuning machine learning models in the study.



An example of report

(the following pages)

AI Vision for Epidemiology

Analysis Results of Face Mask Classification on EPIWATCH® (Research/Demonstration Only)

User: Dr Hang DING
Date: 30 June 2024

Analysis Results

Face Mask Usage (%) : 95.0%

Environment: Indoor (Probability of 63.7%)

Appropriate Mask Wearing (n) : 38

Not/Inappropriate Mask Wearing (n) : 2

Face and/or Face-like Images Detected (n) : 50

Face and/or Face-like Images Excluded (n) : 10

Background:

Appropriate Mask Wearing:
Wearing of a face mask covering nostrils and mouth.

Inappropriate Mask Wearing:
Mask was below the nostrils or even around the neck.

Face and Face-like Images Excluded:
Images contain little information about face mask wearing status. Typical ones include very blurry images, largely occluded, or not real human faces (statues, paintings, face-like objects, etc.).

Face Mask Usage:
Adppropriate Mask Wearings / (Faces Detected - Faces Excluded) * 100%

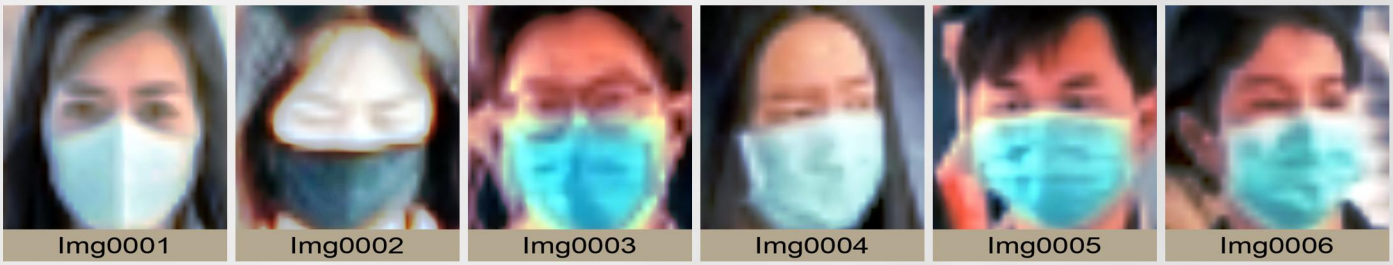
Image Analysed:

Source: UNSW NEWS
Website:
https://www.unsw.edu.au/newsroom/news/2023/03/policing-the-pandemic-didn-t-work--report-shows-where-covid-fine
Publish Date: 14 Mar 2023

Figure 1. The original photo with face images detected.

(Source: UNSW NEWS. See Page 1 for more details.)

Appropriate Mask Wearing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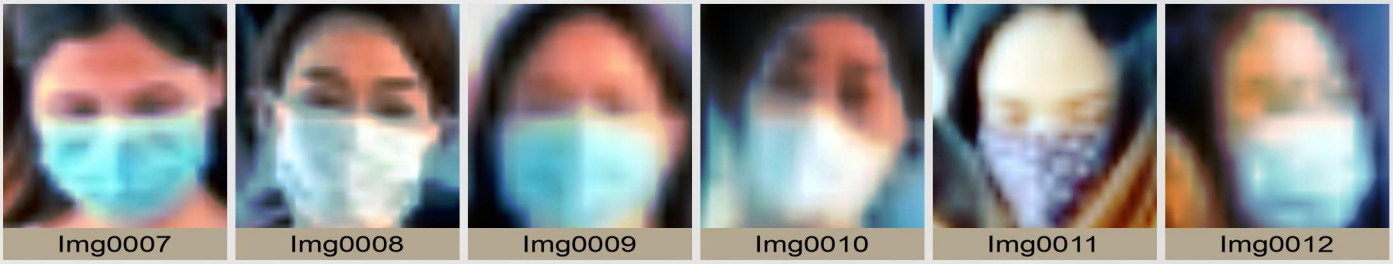
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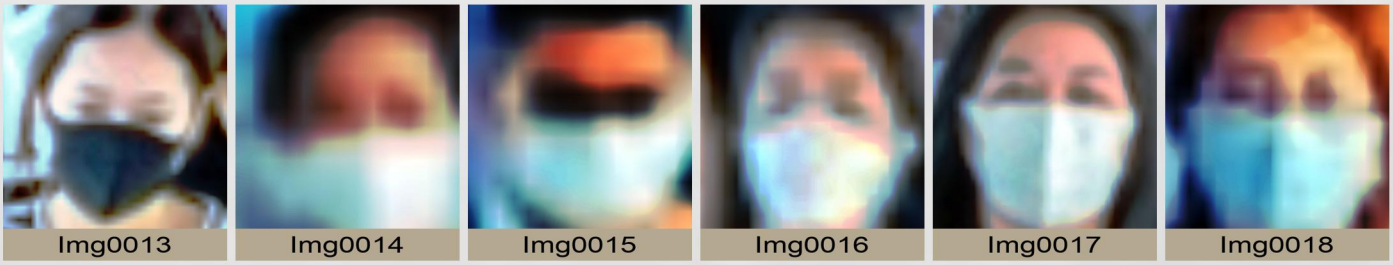
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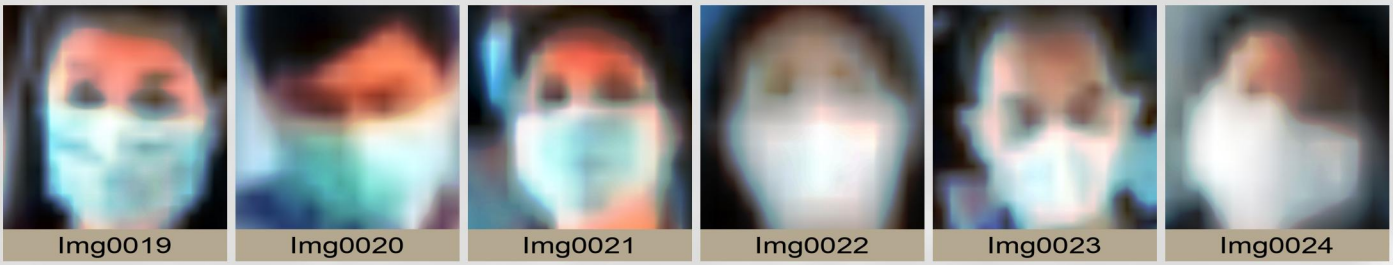
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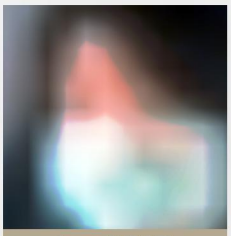
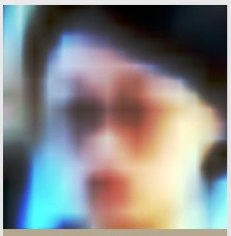
Img0025 Img0026 Img0027 Img0028 Img0029 Img0030


Img0031 Img0032 Img0033 Img0034 Img0035 Img0036


Img0037


Img0038

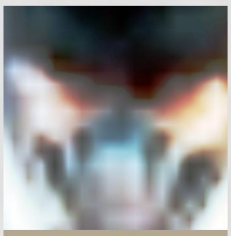
Not or Inappropriate Mask Wearing


Img0039


Img0040

Excluded in Analysis


Img0041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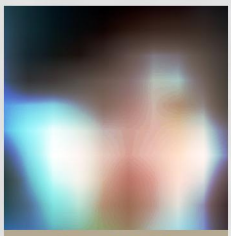
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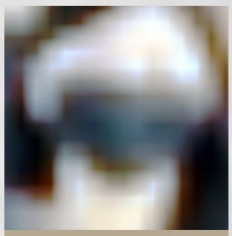
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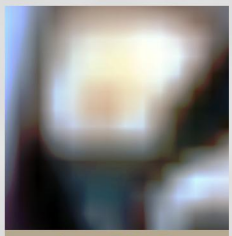
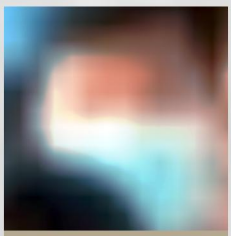

Img0045


Img0046


Img0047


Img0048


Img0049


Img0050