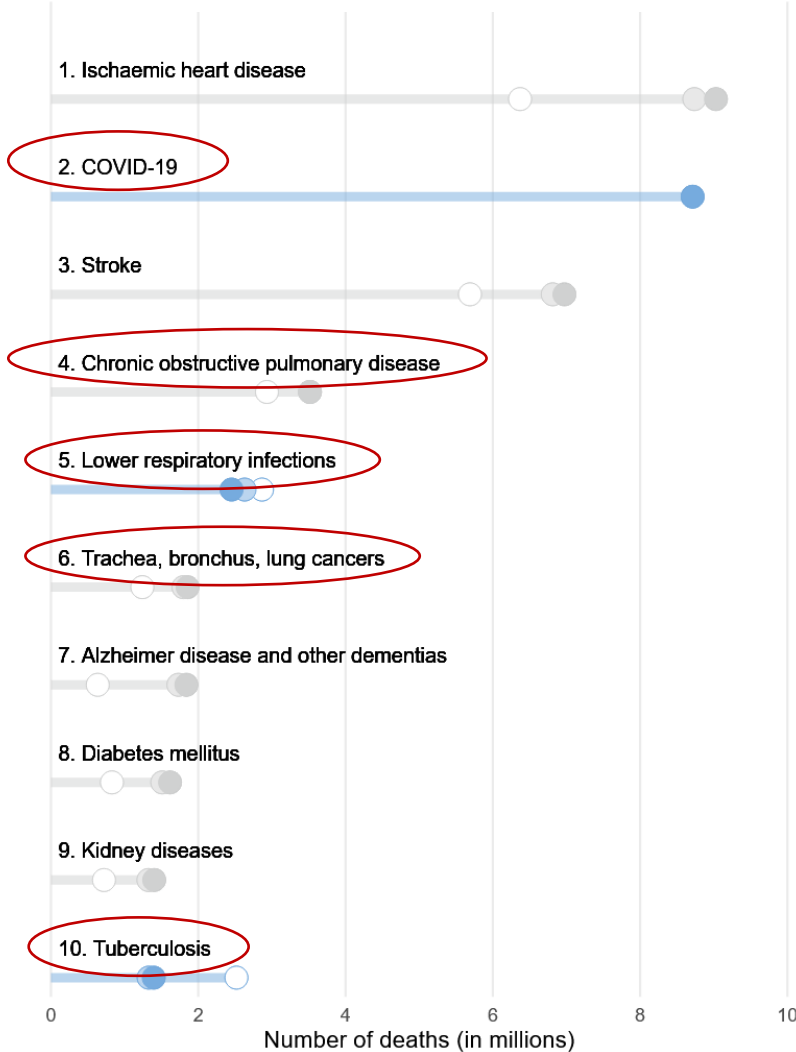


Challenges in Realistic Respiratory Audio AI for Healthcare

Dr. Georgios Rizos



We need cheap early-warning systems

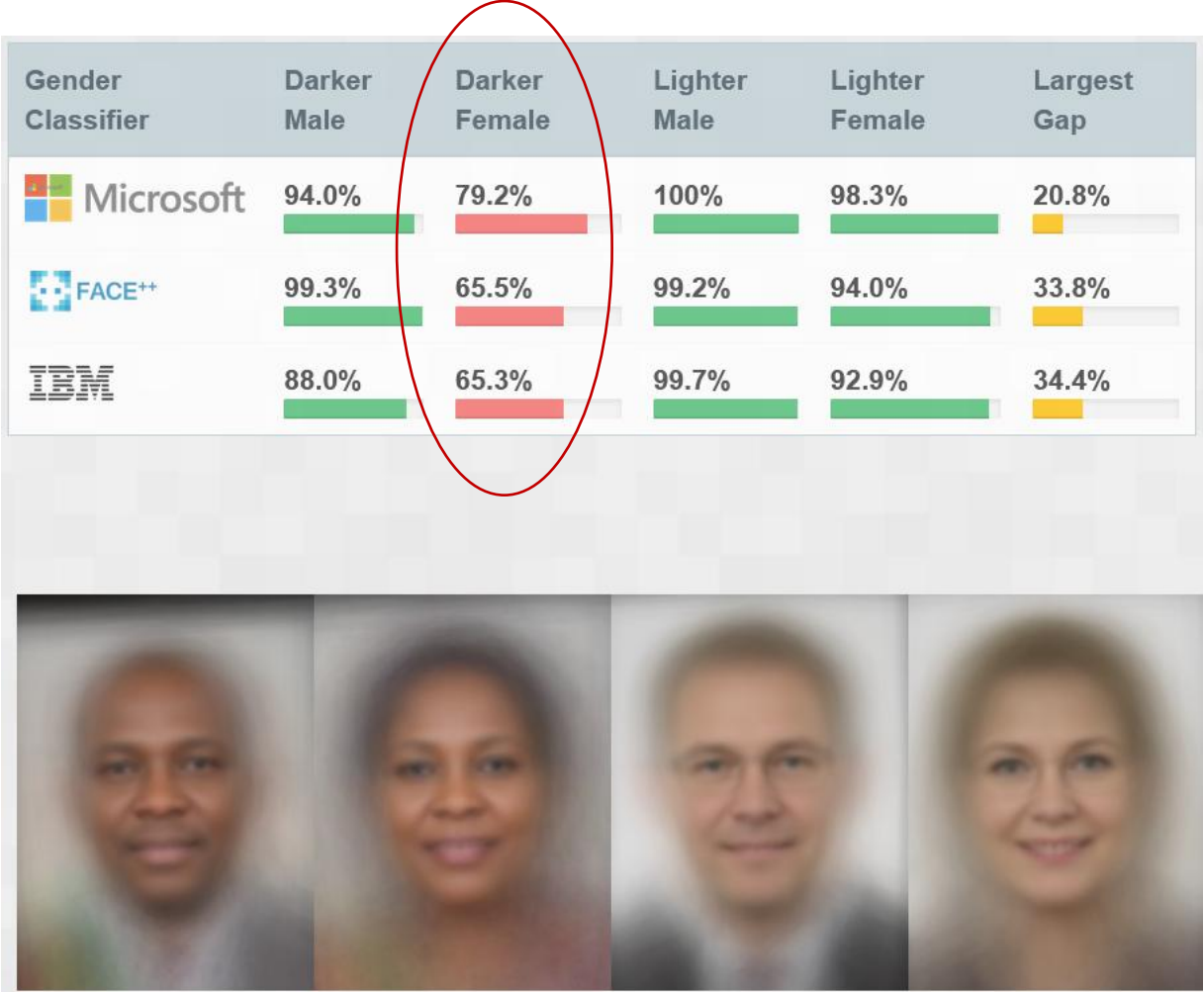
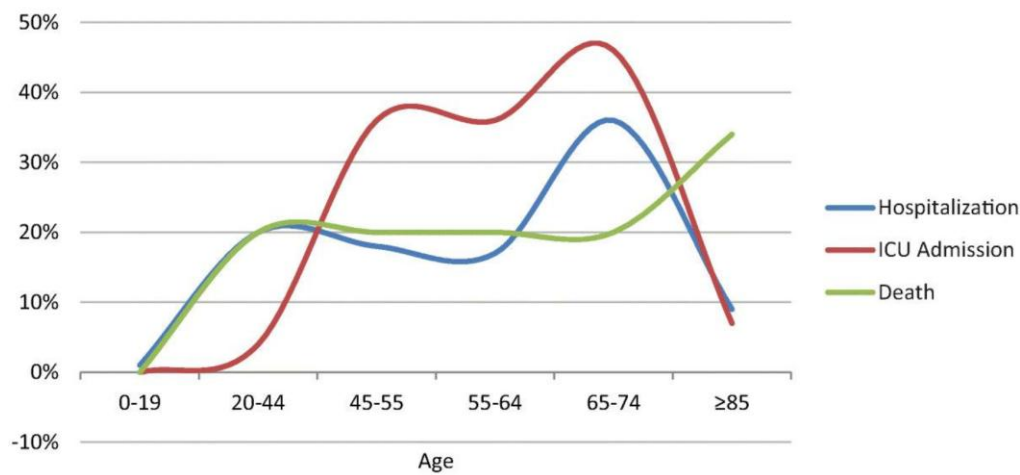


	Direct costs [#] € bn	Indirect costs ¹ € bn	Monetised value of DALYs lost € bn	Total costs € bn
COPD	23.3	25.1	93.0	141.4
Asthma	19.5	14.4	38.3	72.2
Lung cancer	3.35	NA	103.0	106.4
TB	0.54 [#]	#	5.37	5.9
OSAS	5.2	1.9	NA	7.1
Cystic fibrosis	0.6	NA	NA	0.6
Pneumonia/ALRI	2.5	NA	43.5	46.0
Total	55.0	41.4	283.2	379.6

Robust AI that leaves no one behind

COVID-19:

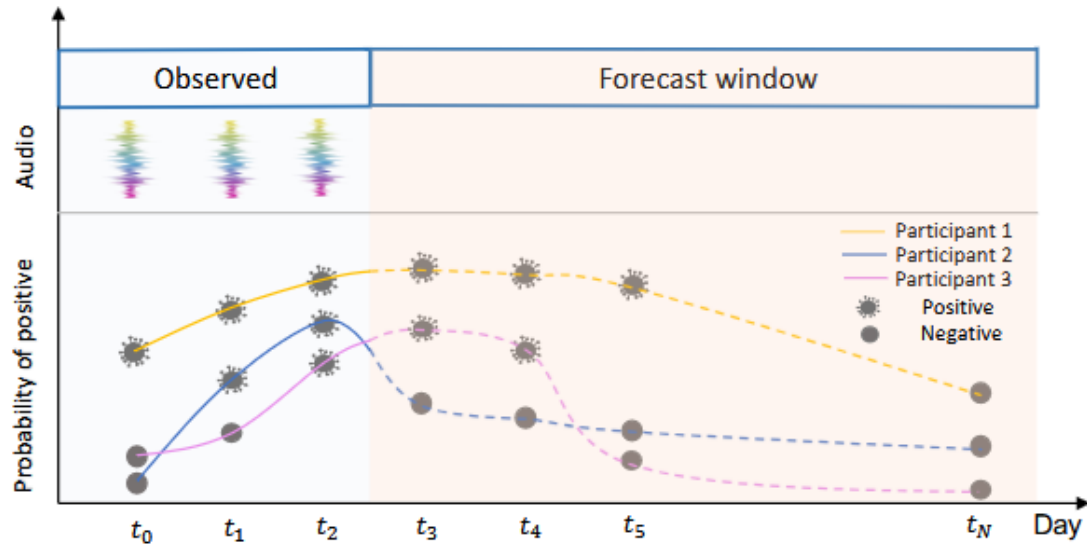
Hospitalization, ICU Admission and Death (Feb. 12 – Mar. 16, 2020)



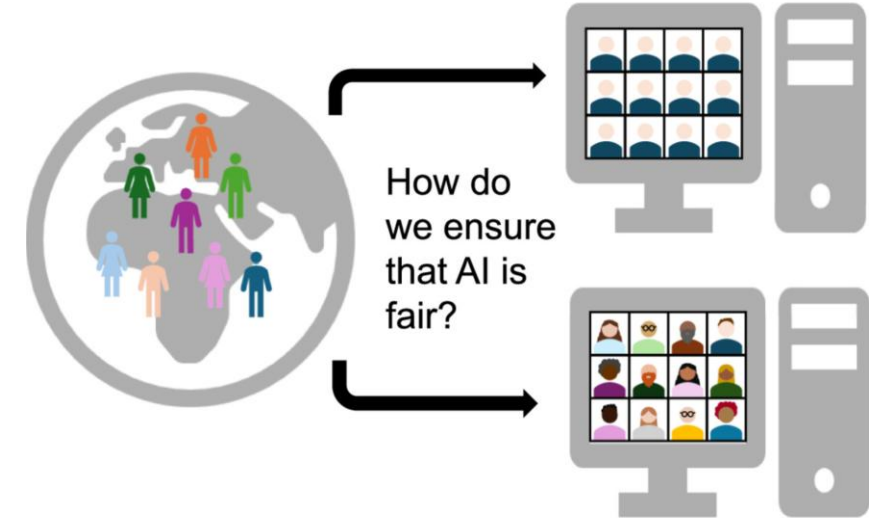
Sanyaolu et al. “Comorbidity and its impact on patients with COVID-19”, SN comprehensive clinical medicine 2020

Buolamwini and Gebru “Gender shades: Intersectional accuracy disparities in commercial gender classification” Conference on fairness, accountability and transparency 2018

A) Personalised respiratory progression



B) Fair respiratory AI



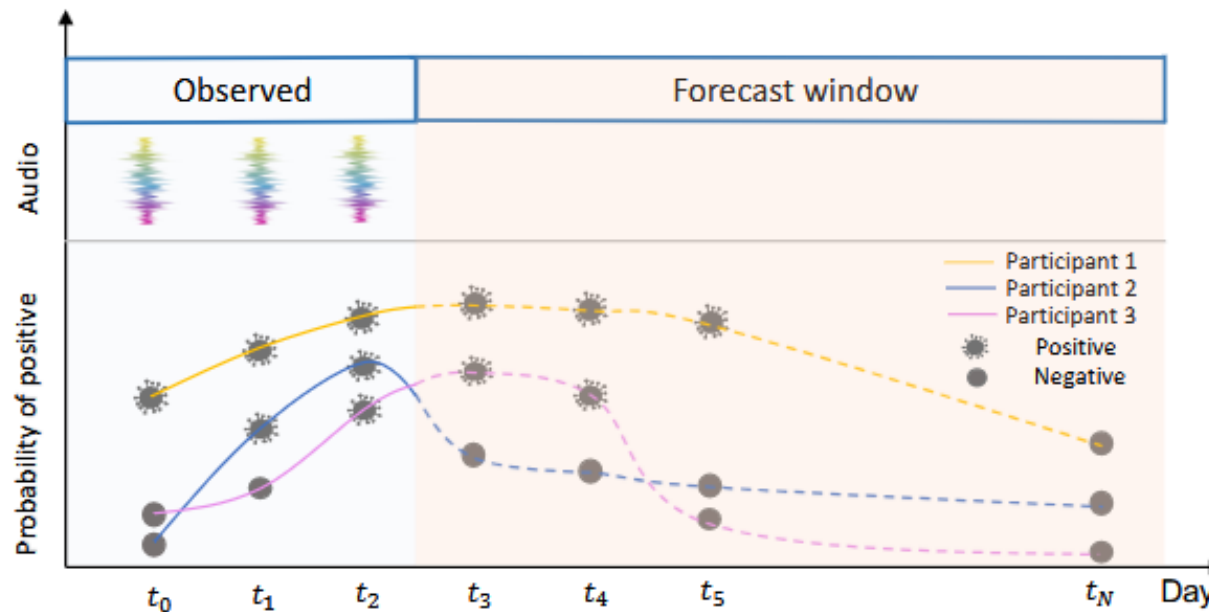
C) Looking forward



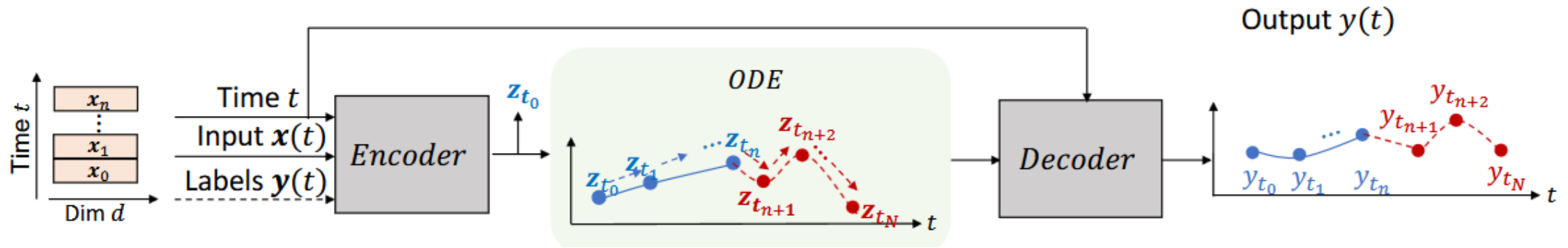
jplenio on pixabay

Individual disease progression forecasting

- Based on a few past observations
- Irregularly sampled time-series
- Data sparsity
- Personalised to individual



CNDP: Conditional Neural ODE processes



CNDP: COVID-19 test case

- Mobile-sourced longitudinal dataset
- 212 participants -- F/M/U: 110/90/12
- Each participant submitted: 5-385 samples

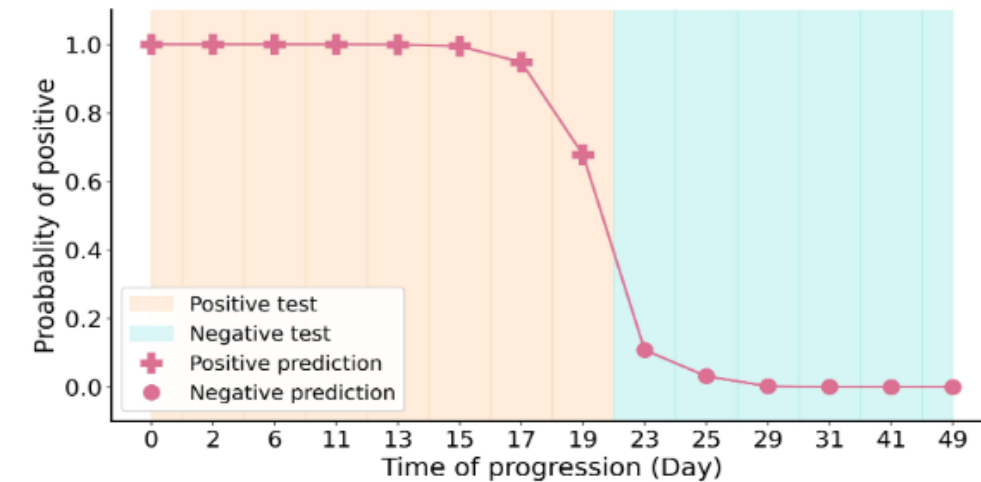
	Forecasting	Systems	UAR	Sensitivity	Specificity
Audio only	One-step-ahead	RNN Δt_1	75.5(71.0-79.5)	73.4(65.6-80.5)	77.6(73.9-81.2)
		RNN Δt_{all}	74.7(70.3-78.8)	73.4(65.5-81.0)	75.9(72.2-79.8)
	Multi-step-ahead	RNN-VAE	74.8(70.5-78.9)	75.0(67.0-82.2)	74.7(70.8-78.3)
		Transformer	75.3(70.3-78.9)	72.7(64.8-80.0)	76.8(73.0-80.7)
		CNDPs	77.1(72.6-80.9)	76.6(68.6-83.6)	77.6(73.8-81.3)
		CNDPs _I	78.1(74.0-81.8)	78.9(71.2-85.7)	77.2(73.1-80.9)
Audio + Labels	Multi-step-ahead	RNN $\Delta t_{all}^{\hat{y}}$	82.5(78.8-85.9)	84.4(78.0-90.4)	80.5(76.9-83.9)
		RNN-VAE $^{\hat{y}}$	75.1(70.5-79.2)	73.4(65.4-80.6)	76.8(73.0-80.7)
		Transformer $^{\hat{y}}$	77.9(73.6-81.5)	79.7(72.5-86.2)	75.9(72.1-79.9)
		CNDPs $^{\hat{y}}$	88.3(84.8-91.5)	84.4(78.0-90.3)	92.3(89.7-94.5)
		CNDPs _I $^{\hat{y}}$	93.6 (90.8-96.1)	90.6(85.2-95.2)	96.7(94.9-98.2)

COVID-19 Sounds App

Upload short recordings of cough and breathing and report symptoms to help researchers from the University of Cambridge detect if a person is suffering from COVID-19. Healthy and *non-healthy* participants welcome.

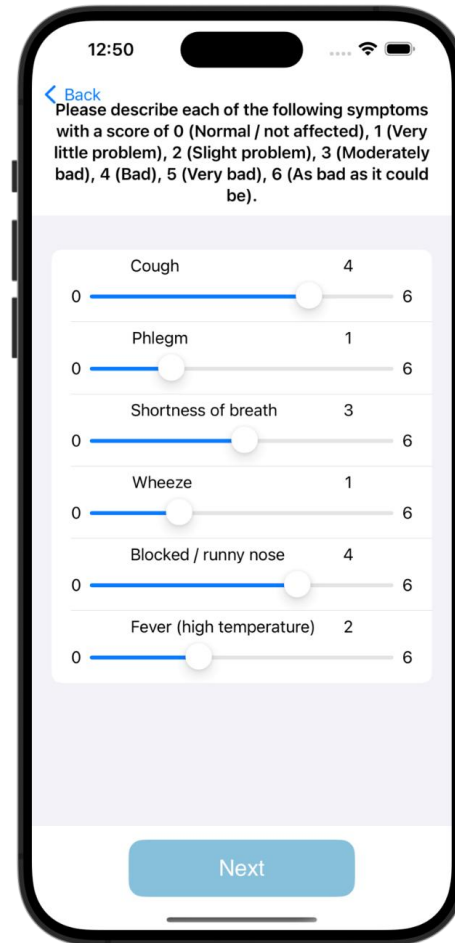
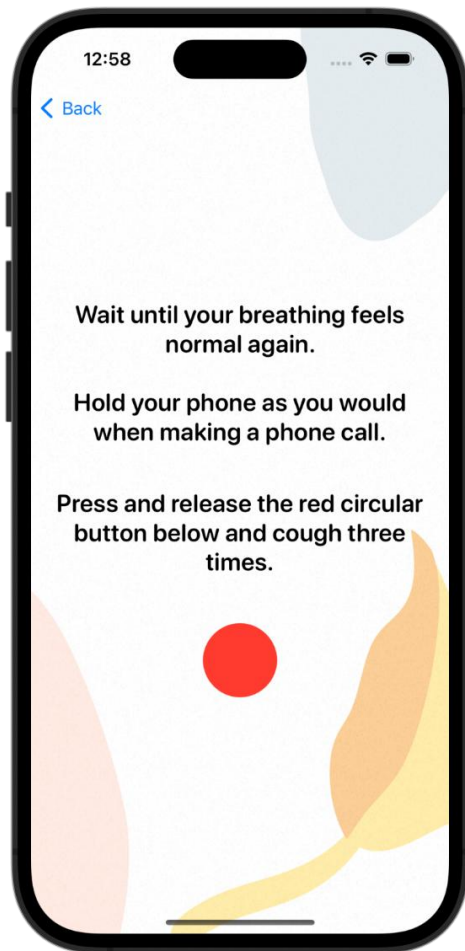


or use the online form



Dang et al. "Conditional neural ODE processes for individual disease progression forecasting: a case study on COVID-19", SIGKDD 2023

EPSRC RELOAD: Respiratory Tract Infections



 **RELOAD** Breath Tracker app

RELOAD: RESpiratory disease progression through LOngitudinal Audio Data machine learning.



iOS

Android



By Evelyn Zhang

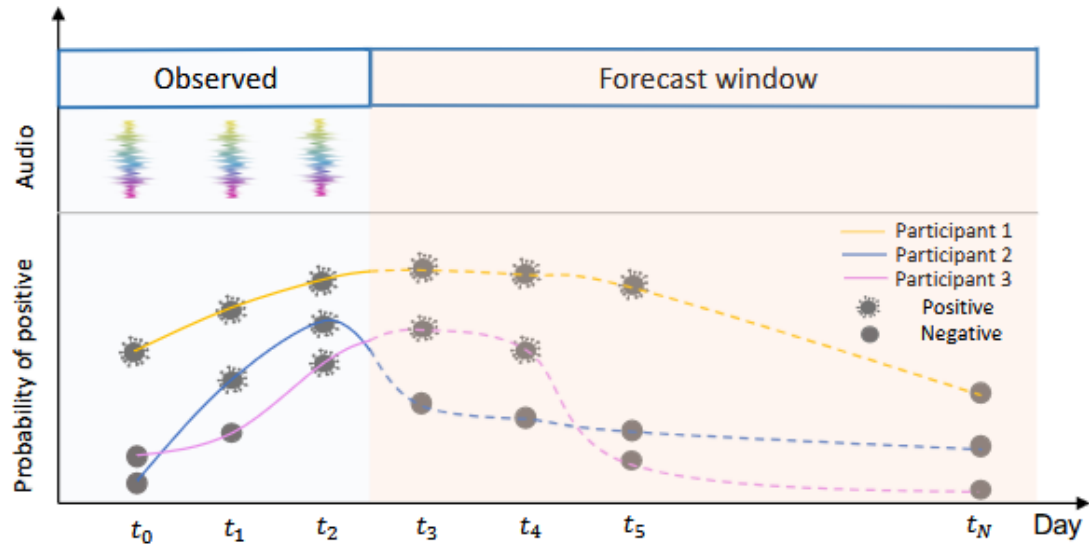
CNDP: Respiratory Tract Infection test case

- Binary RTI detection
- Mobile-sourced longitudinal dataset
- 463 users (178 with at least 1 positive RTI)

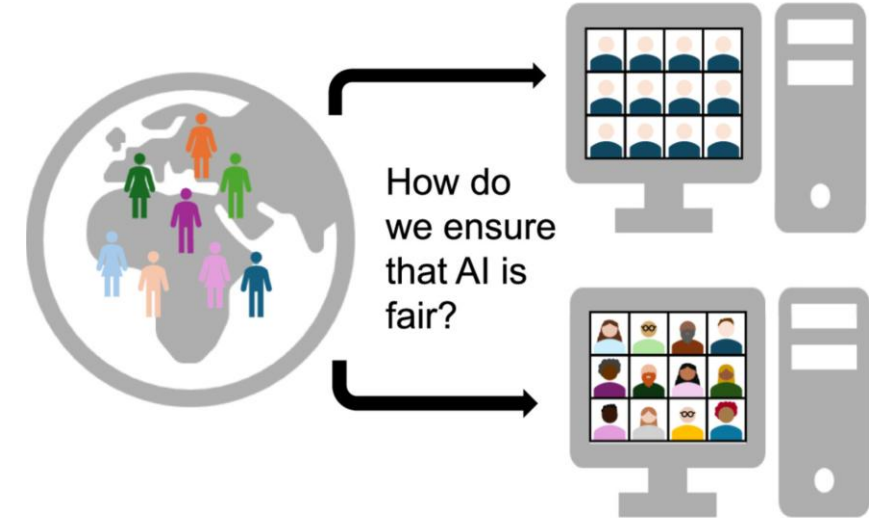
Approach	AU-ROC
PANN features + Gaussian Process	.779
CNDP	.850



A) Personalised respiratory progression



B) Fair respiratory AI



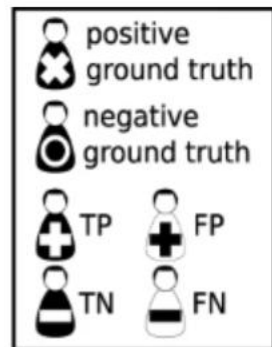
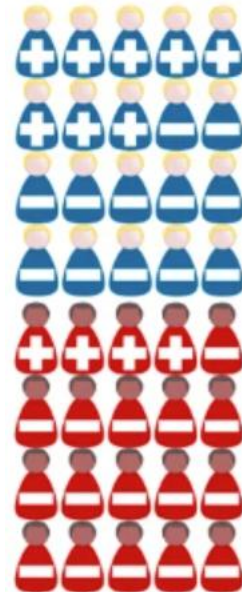
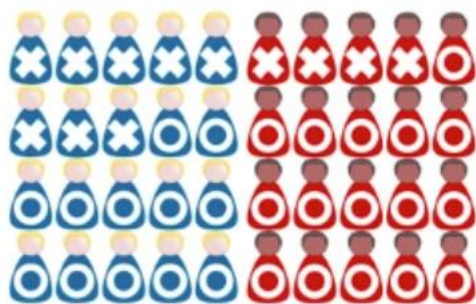
C) Looking forward



jplenio on pixabay

Fairness definitions

Ground truth Model prediction



Group fairness

- Minimise Δ AU-ROC, Δ ECE

Max-min fairness

- Maximise Worst AU-ROC, Worst ECE

Fair methods usually need sensitive info...

...to unlearn bias

- Is this a problem?
 - a. Confidential, or not shared
 - b. Whac-a-mole effect
 - c. Unknown bias dimensions a-priori



Wikipedia

Group-agnostic methods for audio

- Selected experiments setup:
 - Wav2Vec 2.0 Base encoder
 - UK COVID-19 data subset
- Revisiting robust methods:
 - Weight averaging (SWAD)
 - Flatness seeking (SAM)
 - Model Ensembles

#	Train	Devel	Test	F/M	A1/A2/A3
positive	366	204	314	532/352	378/419/87
negative	634	296	686	909/707	449/697/470
Σ	1,000	500	1,000	1,441/1,059	827/1,116/557

Binary COVID-19 detection

Method	UAR \uparrow	worst-UAR \uparrow	Δ -UAR \downarrow	ECE \downarrow	worst-ECE \downarrow	Δ -ECE \downarrow
W2V2B	.640 \pm .047	.616 \pm .048	.114 \pm .013	.075 \pm .036	.157 \pm .047	.115 \pm .045
W2V2B + SAM	.640 \pm .057	.611 \pm .053	.103 \pm .017	.060 \pm .056	.138 \pm .052	.087 \pm .054
E-W2V2B	.653	.642	.122	.106	.160	.080
E-W2V2B + SAM	.676	.668	.089	.020	.078	.039



SUBMITTED

Future pandemics?

Disease X

“as the COVID-19 pandemic demonstrated,
infectious diseases do not respect borders”



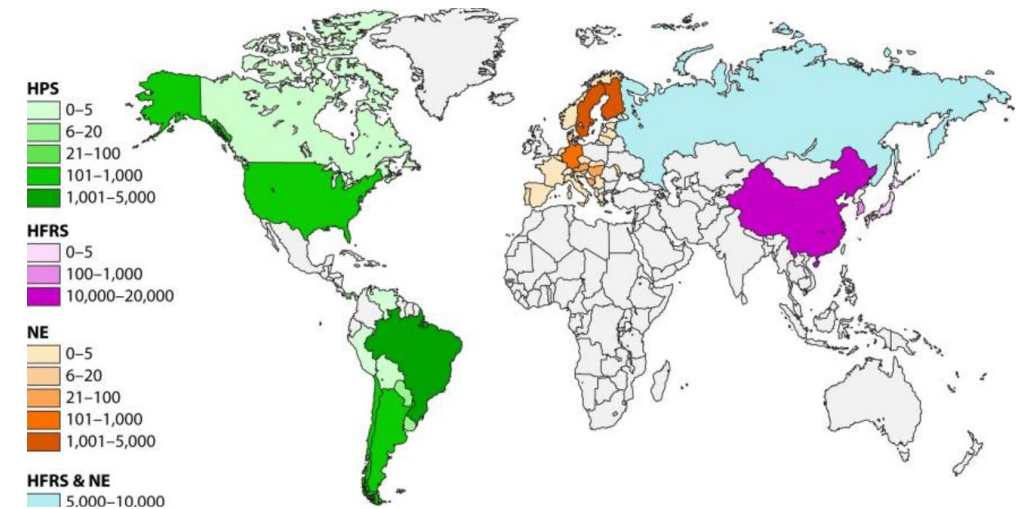
Rare and deadly diseases?

B B C

What is hantavirus, disease that killed Gene Hackman's wife?

“The CDC reported 864 cases of hantavirus in the US between 1993 and 2022.”

“mortality rate is approximately 38%”



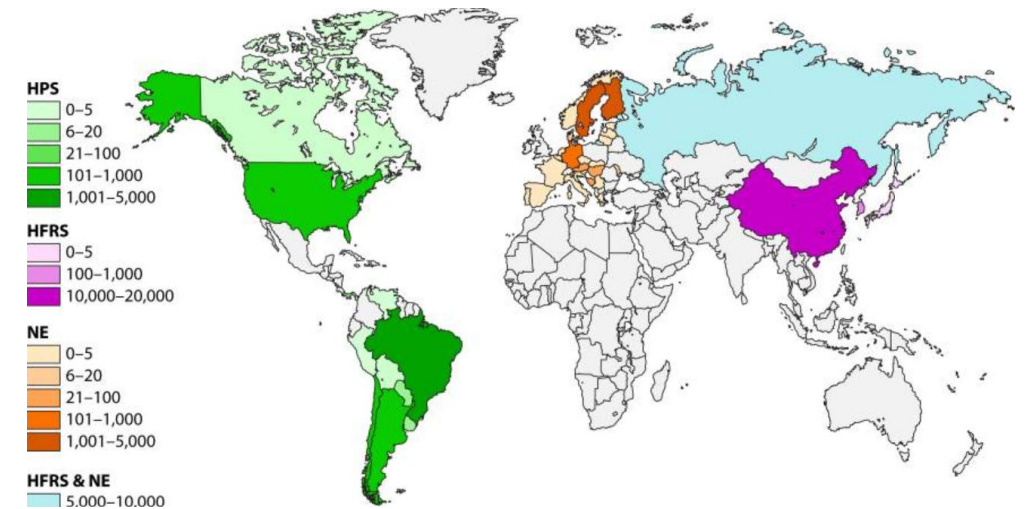
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Cheap early-warning systems

Robust AI to leave no one behind