Adversarial Regression Training for Visualizing the Progression of Chronic Obstructive Pulmonary Disease with Chest X-Rays

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Introduction

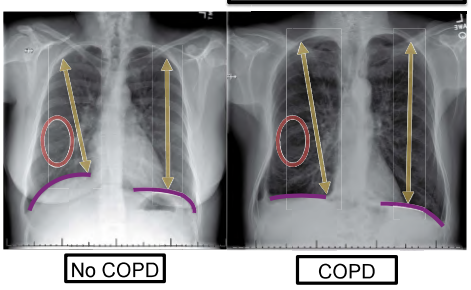
Motivation:

- Chronic obstructive pulmonary disease (COPD): third leading cause of death[1] and not reported by radiologists
- We trained regression CNN: COPD screening with chest x-ray
- *Explainability* wanted for adoption, communication and debugging. Challenge: model *explainability* for regression

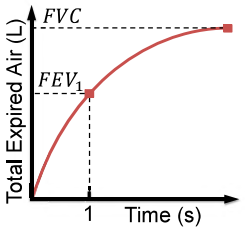
What regions of the image are weighted positively in the decision to output this class? → What would this image look like if it had this other regression value?

Our approach: *explainability* for regression by adversarial training

COPD evidence in x-ray



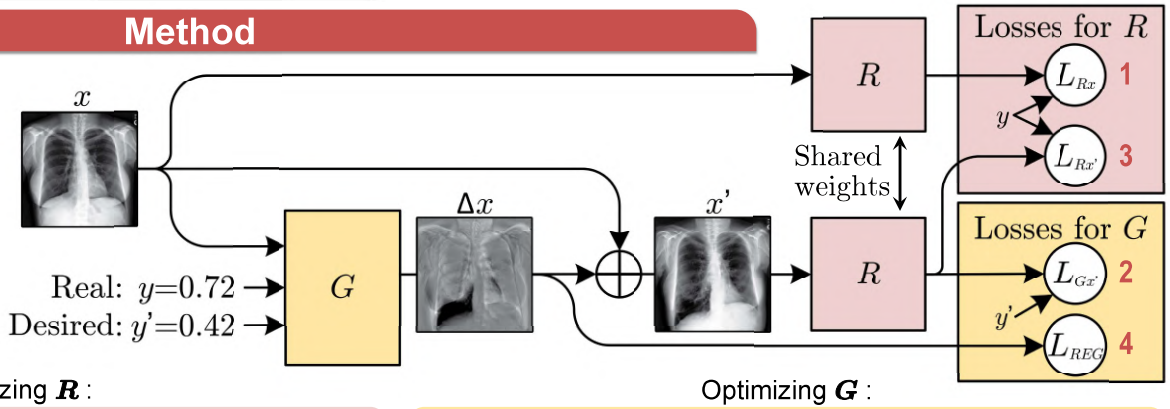
Pulmonary Function tests (PFTs)



COPD: $\frac{FEV_1}{FVC} < 0.7$

Method

x = original image linked to value y
x' = modified image linked to y'
Δx = the generated disease effect
$y = FEV_1/FVC$



Loss terms:

Optimizing $\boldsymbol{R}$:

1. $\boldsymbol{R}$ performs the original regression task $L_{Rx} = |R(x) - y|_{L1}$
3. Adversarial: $\boldsymbol{R}$ ignores changes from G $L_{Rx'} = |R(x') - y|_{L1}$

Optimizing $\boldsymbol{G}$:

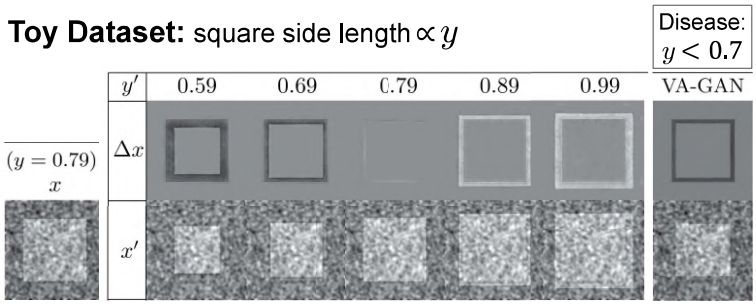
2. $\boldsymbol{G}$ modifies R's output to desired value $L_{Gx'} = |R(x') - y'|_{L1}$
4. $\boldsymbol{G}$ modifies only what is needed $L_{REG} = |\Delta x|_{L1}$

Experiments and Results

Baseline: VA-GAN [2]:

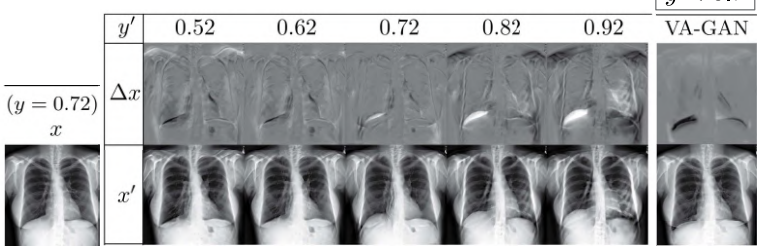
- Critic instead of regressor (generated vs. real with disease)

Toy Dataset: square side length $\propto y$

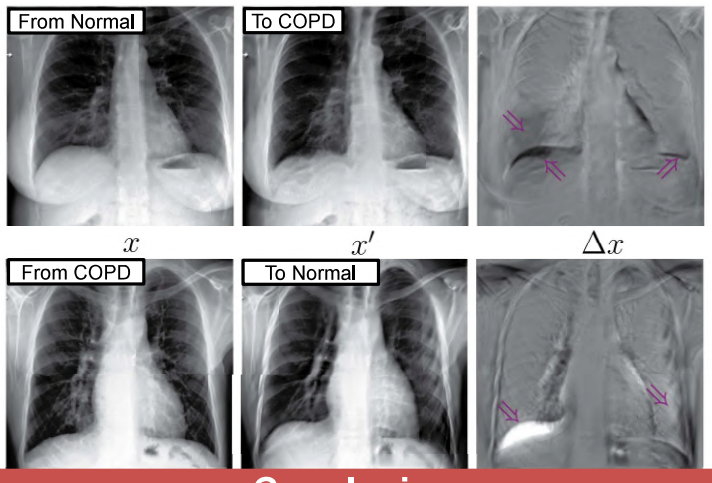


Chest x-ray dataset:

- Patients with chest x-ray and a PFT
- Longitudinal data registered for calculating scores



Normalized cross-correlation	VA-GAN	Our
Toy dataset	0.78	**0.853**
Chest x-ray	0.012	**0.127**



Conclusion

- Regression target inclusion in formulation improves results.
- Learned changes agree with radiologists on COPD effects
- Realistic images with no real/fake discriminator
- A step toward building explainable models for regression

Code available! github.com/ricbl/vrgan

[1] Lozano, Rafael et al.: Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: A systematic analysis for the Global Burden of Disease Study 2010. In: The Lancet (2012)
[2] Baumgartner et al.: Visual feature attribution using Wasserstein GANs. In: CVPR (2018)