Current Use of Generative Adversarial Networks (GANs) in Cardio-Imaging and Future Applications as Educational Tools in Cardiology

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Background:

Supervised Deep Learning is currently used in many medical image analysis tasks. However, a major limiting factor for this paradigm is its dependence on vast amounts of annotated training data. Generative Adversarial Networks (GANs), unsupervised learning algorithms, have shown the capabilities to generate images with unprecedented realism(Figure1). The purpose of this research is to do a systematic review of the current application of GANs in cardio-imaging and to discuss possible applications of GANs in medical education.

Research questions leading this research are:

1. What types of GANs are being utilized in cardio-imaging?
2. What are the tasks that GANs fulfill in cardio-imaging?
3. What are the cardio-imaging modalities being used in GANs?

Methods:

In order to answer these research questions, a systematic review was done and 90 research articles were analyzed. Since the advent of GAN in 2014, 16 studies have been conducted on how GANs assist cardio-radiologist. In this review, I have covered the medical imaging application of GAN published until May 2019. Papers published in this time range propose using GANs in medical applications of denoising, reconstruction, segmentation, classification, and synthesis. These papers were applied to different image modalities such as Cardiac MR, CT, CT Angiography (CTA), chest X-Ray, and Ultrasound. Descriptive statistic was run and the findings of the review were analyzed by Tableau visualization software 2019.2.

Results:

The most commonly used GANs in cardiology are: DCGAN, CycleGAN and Semi-Supervised GANs(SGAN). Table 1 shows the types of GANs and tasks along with imaging modality

Imaging Modality	Type of GAN	Task	Anatomy	Task
			Heart	
Cardiac MRI	Other	Classification		Classification
CT	DCGAN	Denoising		Denoising
	SAGAN	Denoising		Denoising
CT Angiography	CycleGAN	Denoising		Denoising
	WGAN	Synthesis		Synthesis
Echo	Semi-supervised GAN	Classification		Classification
MR	CGAN	Segmentation		Segmentation
	DCGAN	Segmentation		Segmentation
	Other	Segmentation		Segmentation
	Semi-supervised GAN	Reconstruction		Reconstruction
MR&CT	CycleGAN	Synthesis		Synthesis
	Other	Synthesis		Synthesis
X-ray	DCGAN	Classification		Classification
	Semi-supervised GAN	Classification		Classification

Table 1. Commonly used GANs in Cardiology

Discussion:

DCGANs outperformed the other techniques for cardiovascular abnormality detection in chest X-rays with the accuracy of 84.19. DCGANs also gave promising results in reducing noise in low-dose CT and producing images for more accurate coronary calcium quantification¹. DCGANs synthesized MRI images and CT data for cardiac structures segmentations and achieved very promising results². CycleGAN was used in multiphase coronary CTA and was found denoising method significantly increases the diagnostic quality of the CTA images³. CycleGAN showed to improve the accuracy of a cardiac segmentation by 16%⁴. SGANs was used for classification in cardio-imaging and showed an accuracy of 94.4% for echocardiographic classification⁵.

Conclusion:

Although GAN s have been used in cardio-imaging in various tasks, they have never been used as a tool to educate cardio-radiologists. Since medical images pose unique legal and technical challenges that make it difficult to widely disperse images for training, GANs have a potential to be used as a teaching tool to educate cardio-radiologists. GANs also could be used in generating heart sounds to train medical students for diagnosing heart diseases. Possible ethical issues of GANs in cardiology should also be discussed

Figure 1. Structure of GANs. Image Source: KDNuggets-Generative Adversarial Networks

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