WaveNet - Generative Music Production

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WaveNet in General

- Developed by DeepMind in London
- Generate raw speech signals with subjective naturalness never before reported in the field of Text-to-Speech (TTS)
  (Oord et al., 2016)
- Performance improvement by over 50%
  (van den Oord and Dieleman, 2016)
- Advantage : one model for different purposes

WaveNet in General

- Architecture based on dilated causal convolutions
- WaveNets provide a generic and flexible framework for many applications relying on audio generation :
  - Text-to-Speech
  - Music generation
  - Speech enhancement
  - Voice conversion
  - Source separation

Source : (Oord et al., 2016)

Model Explanation - Theoreticaly

- Generative model operating on raw audio waveform
- Joint probability of a waveform is factorised as product of conditional probabilities
- Each audio sample is therefore conditioned on the samples at all previous timesteps
- Conditional probability distribution is modelled by stack of convolutional layers
- No pooling layers in network
- Output of the model has same time dimensionality as input

Source : (Oord et al., 2016)

Model Explanation - Visual

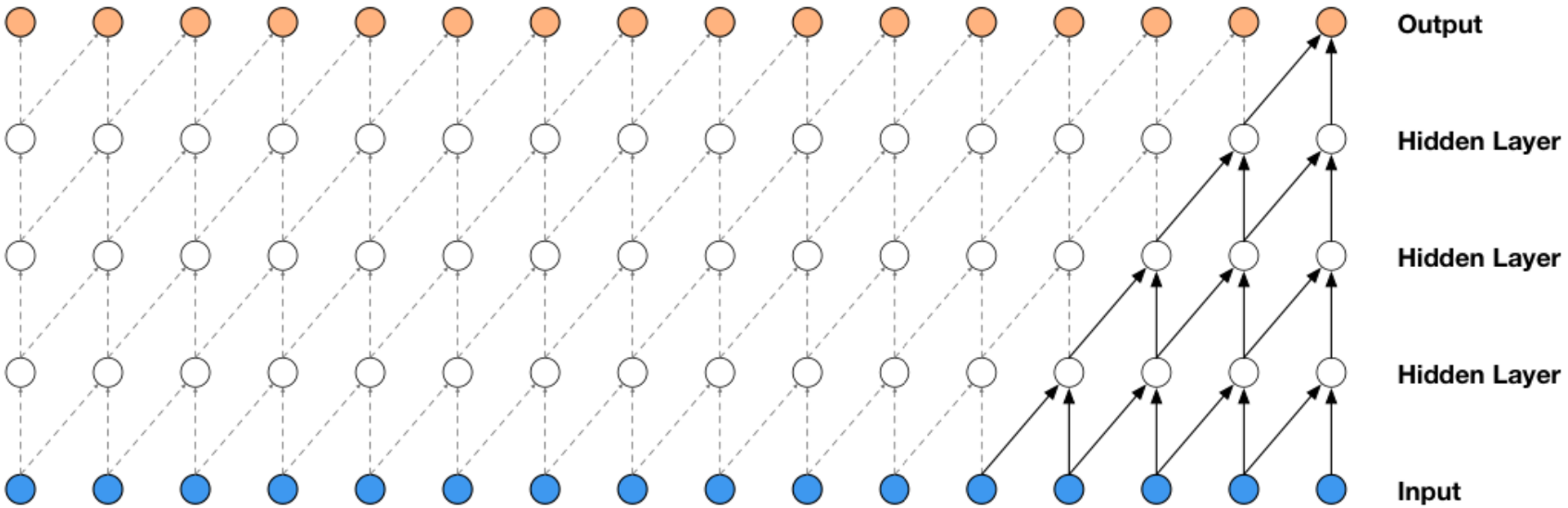


Figure : Visualization of a stack of causal convolutional layers
Source : (Oord et al., 2016)

Model Explanation - Causal Convolutions

- Main ingredient of WaveNet are causal convolutions
- Based on that, the model cannot violate the ordering in which the data is modeled
- Predictions emitted by model at timestep t cannot depend on any of the future timesteps
- At training, conditional predictions for all timesteps can be made in parallel (all timesteps of ground truth x are known)

Source : (Oord et al., 2016)

Model Explanation - Causal Convolutions

- At generation of outputs with model, predictions are sequential : after each sample is predicted, it is fed back into network to predict next sample
- Models with causal convolutions do not have recurrent connections, they are typically faster to train than RNNs
- Problem of causal convolutions is : they require many layers, or large filters to increase the receptive field

Source : (Oord et al., 2016)

Model Explanation - Dilated Convolutions

- A dilated convolution is a convolution where the filter is applied over an area larger than its length by skipping input values with a certain step
- It is equivalent to a convolution with a larger filter derived from the original filter by dilating it with zeros, but significantly more efficient
- Similar to pooling or strided convolutions, but here the output has the same size as the input
- Stacked dilated convolutions enable networks to have very large receptive fields with just a few layers

Source : (Oord et al., 2016)

Model Explanation - Visual

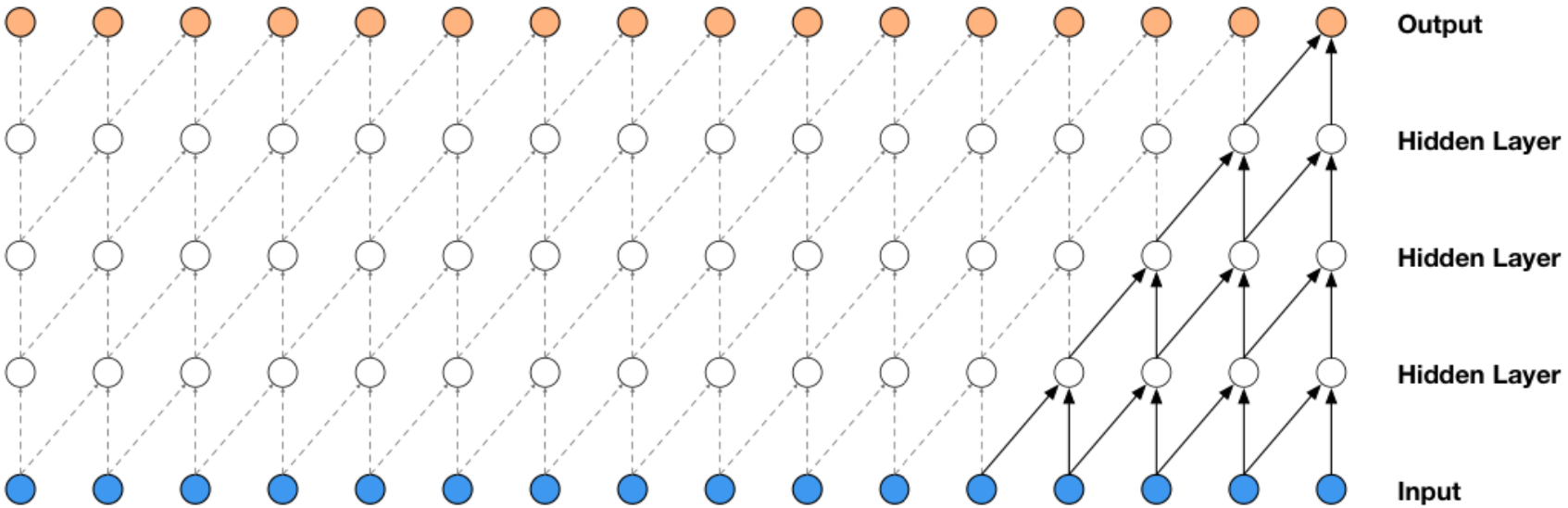


Figure : Visualization of a stack of dilated causal convolutional layers
Source: (Oord et al., 2016)

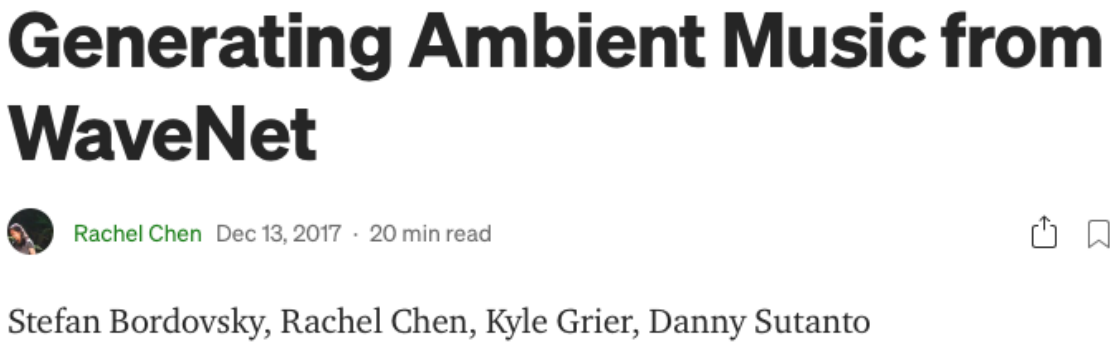
Music Production with WaveNet

- "WaveNets can be used to model any audio signal"
- Unlike the TTS experiments networks were not conditioned on an input sequence telling it what to play (such as a musical score)
- Instead : simply let it generate whatever it wanted to
- Fact that directly generating timestep per timestep with deep neural networks works at all for 16kHz audio is really surprising

Source : (van den Oord and Dieleman, 2016)

Implementation Example

Let's have a look at the Results Chen written down in following article :



Generating Ambient Music from WaveNet

Rachel Chen Dec 13, 2017 · 20 min read

Stefan Bordovsky, Rachel Chen, Kyle Grier, Danny Sutanto

Source : Medium (Chen, 2017)

Implementation Example - Prerequisites

- Model trained on Tensorflow implementation of WaveNet
- 150 000 steps at a default of 0.001 learning rate
- Amazon Web Services' p2.xLarge EC2 instance to train the WaveNet model with a GPU
- 118 500 steps trained in approximately 3.5 days (then AWS costs get to high) :
  - with each step taking roughly 2.5 seconds
  - their laptops took approximately 1 minute just to train one step

Source : Medium (Chen, 2017)

Implementation Example - Some Results

- Based on Happy Music from YouTube the model results are :
  - 9950 steps
  - 10800 steps
  - 14450 steps
  - 25650 steps

Source : Medium (Chen, 2017)

Implementation Example - Challenges

- Very much iterations are needed in order to achieve approximately good results
- Model requires at least 20 000 steps to generate something somewhat recognizable
- And around 80 000 steps for something somewhat coherent
- Learning on local machines takes very long for only semi good results

Source : Medium (Chen, 2017)

Implementation Example - Chances

- Scientist at DeepMind implemented a model playing Piano :
  - ▸ WaveNet Piano example (van den Oord and Dieleman, 2016)
- Advantage is, that they input exactly one instrument
- WaveNet achieves good results on simple inputs
- Complex inputs require a lot of learning steps

Wrap up

- WaveNet is basically a good model for generating music
- Good results can be achieved quickly with individual instruments
- If whole songs are used as input, the model has to make significantly more learning steps
- This extensive learning is very computationally, time-consuming and costly

Bibliography

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Oord, A. v. d., Dieleman, S., Zen, H., Simonyan, K., Vinyals, O., Graves, A., Kalchbrenner, N., Senior, A., and Kavukcuoglu, K. (2016). Wavenet: A generative model for raw audio.

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