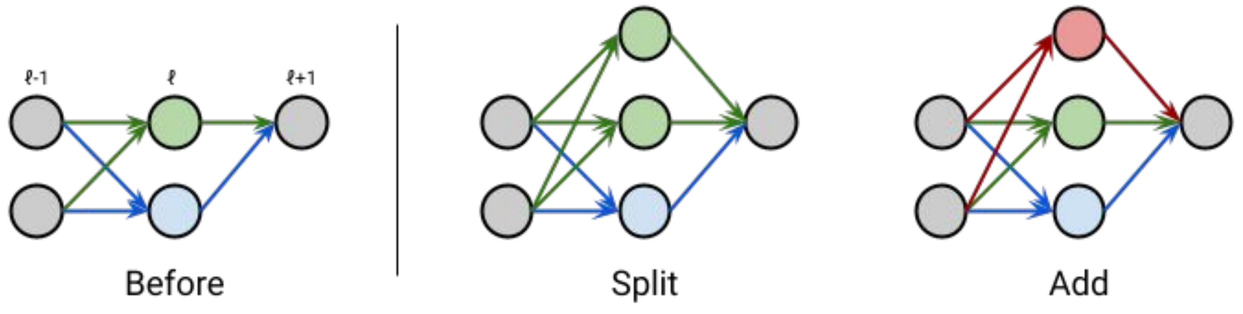
GradMax:
Growing Neural Networks using Gradient Information

Utku Evci, Bart van Merriënboer, Thomas Unterthiner, Max Vladymyrov, Fabian Pedregosa

- Growing neural networks can be useful at:
    - **Continual learning** (Progressive Nets)
    - **Efficient architecture search** (Firefly, and others)
    - **Faster training** & experimentation (OpenAI Dota2, Net2Net)

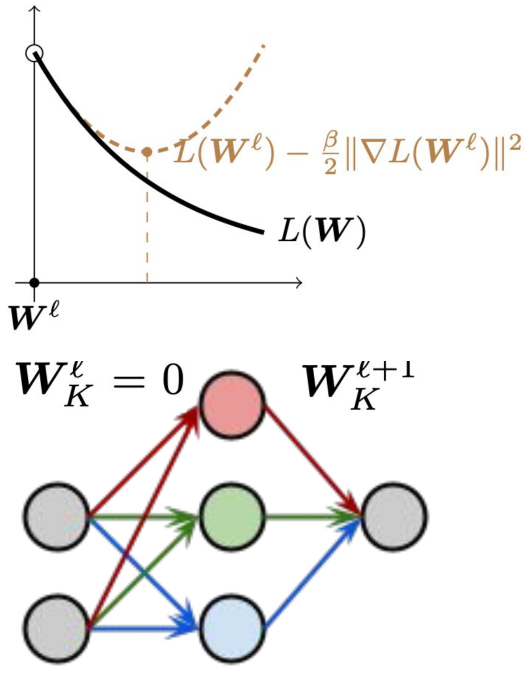


Net2Net (Chen et al., 2016), Taylor (Liu et al., 2019)

Random (Berner et al., 2019), Convex NN (Bengio et al., 2006)

GradMax

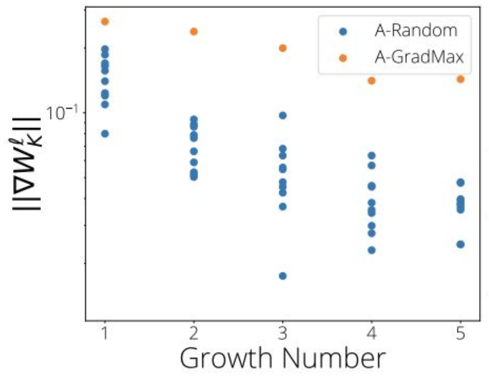
- Incoming weights are set to zero.
- Outgoing weights are initialized to maximize the gradient of incoming weights
- This problem reduces to a spectral problem where the top-K eigenvalues correspond to the new outgoing weights.



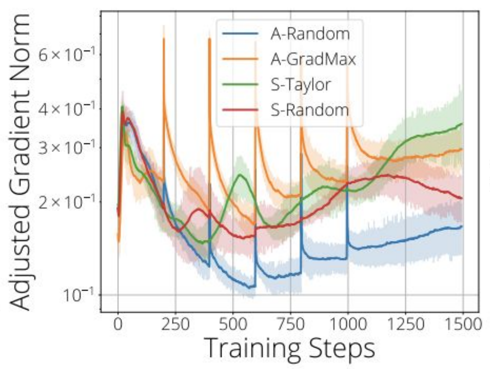
$$\max_{W_K^{\ell+1}} \mathbb{E}_D\left[\left\|\frac{\partial L}{\partial W_K^\ell}\right\|_F^2\right], \quad \text{s.t. } \|W_K^{\ell+1}\| = 1$$

Experiments using Student/Teacher Task (Lawrence et al., 1997)

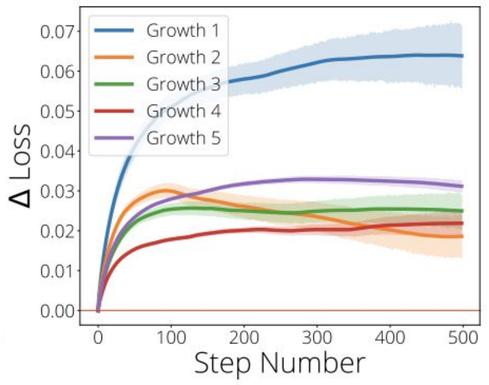
- m_i input nodes, m_h hidden nodes and m_o output nodes (m_i:m_h:m_o).
- N=1000 data points are sampled from a random teacher f_t(x)=y.
- We grow MLPs every 200 steps such that final student architecture is equivalent to the teacher architecture (Global minima at 0 loss).



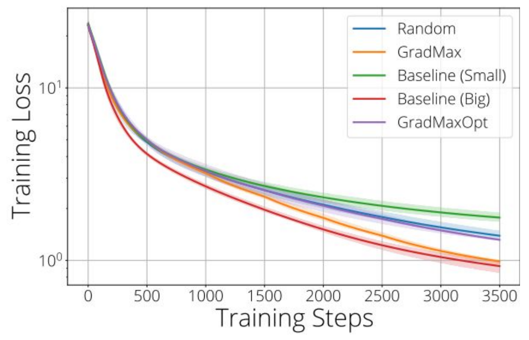
(a) After Growth



(b) During Training



(c) After N Steps

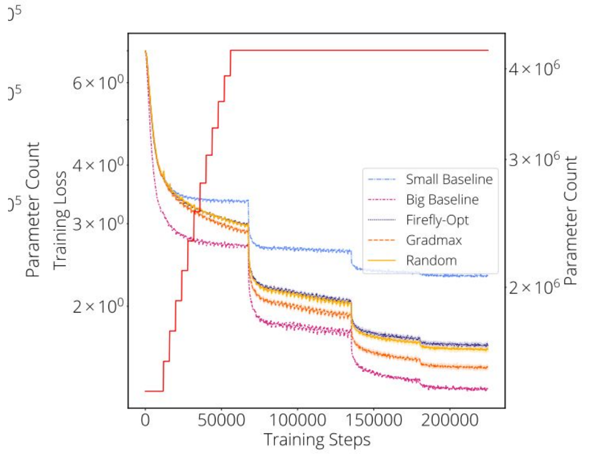


(b) Large ($K = 5,\ f_t = 100:50:10$)

Experiments Image Classification

Dataset	Architecture	Baseline-S	Baseline-B	Random	Firefly	Gradmax
CIFAR-10	WRN-28-1	89.9±0.3	92.9±0.2	90.6±0.2	**90.8±0.3**	**91.1±0.1**
	VGG11	84.1±0.1	86.6±0.3	83.8±0.6	**84.0±0.2**	**84.4±0.4**
CIFAR-100	WRN-28-1	63.7±0.0	69.3±0.1	**66.7±0.4**	66.5±0.1	**66.8±0.2**
ImageNet	Mobilenet-V1	55.0±0.0	70.8±0.0	66.9±0.3	66.4±0.1	**68.6±0.2**

BN	Inverse	Baseline-S	Baseline-B	Random	Firefly	Gradmax(-Opt)
✗	✗	89.9±0.3	92.9±0.2	90.6±0.2	90.8±0.3	91.1±0.1
✗	✓			92.1±0.2	92.2±0.2	92.4±0.1
✓	✗	90.2±0.3	93.4±0.1	92.9±0.1	92.9±0.1	93.0±0.1
✓	✓			92.8±0.1	92.8±0.2	92.9±0.2



(d) MobileNet-v1 / ImageNet