Poincaré GloVe: Hyperbolic Word Embeddings

International Conference on Learning Representations 2019
ICLR 19 - (2019 NLP GROUP STUDY)

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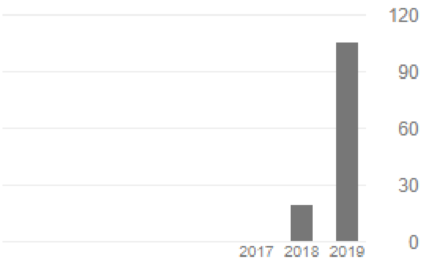

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Machine Learning   Representation Learning   Graph Representation Lear...   Artificial Intelligence

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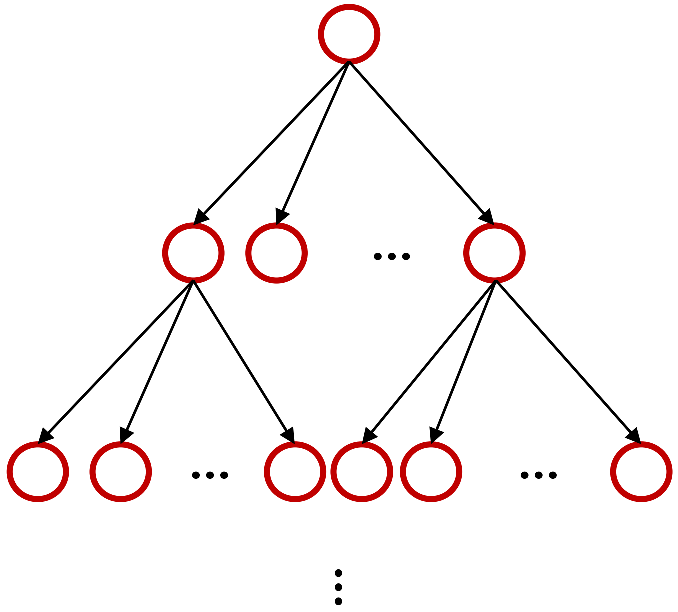
- Ondrej Skopek — Software Engineer, Google

– Recap

Characteristics(?) of tree structured graph



Suppose there are b branching factors on each nodes

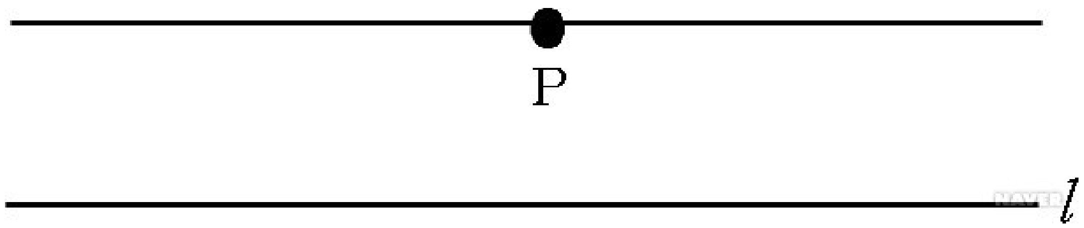
At level l, there are $(b+1)b^l$ nodes

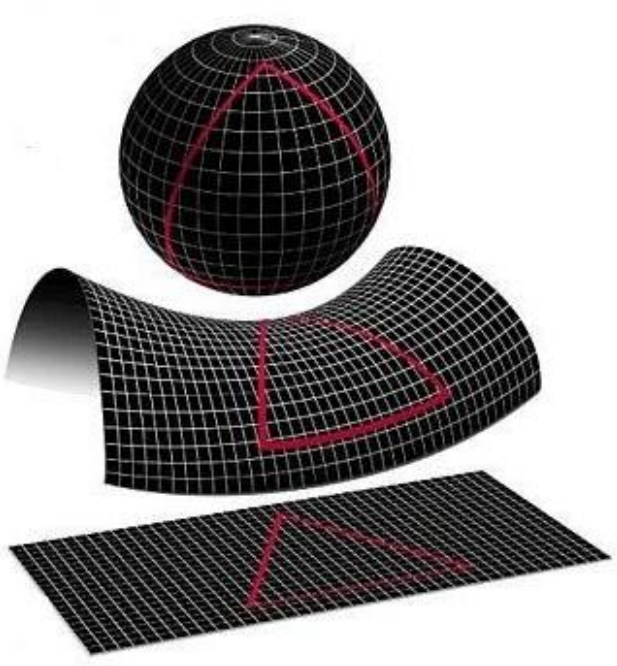
There are $\frac{\left((b+1)b^l-2\right)}{b-1}$ nodes on a level less or equal than l

Note : the # of nodes are exponentially increasing as level l (distance to the root of the tree) increases

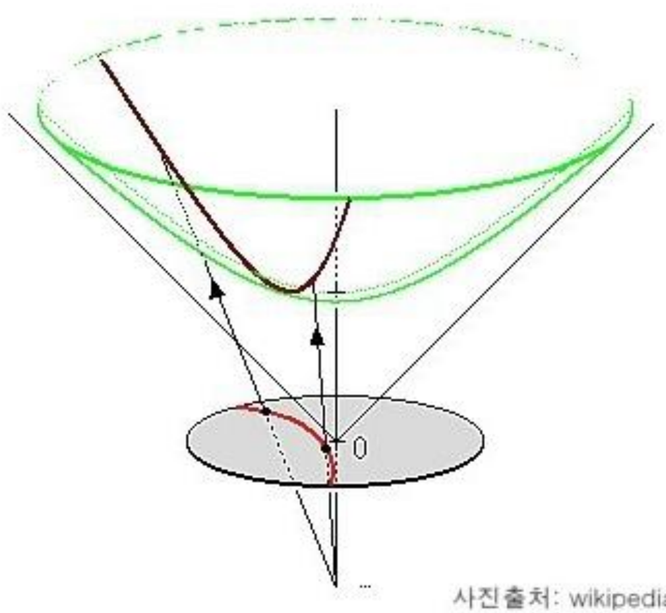
– Recap

> 선 밖의 한 점을 지나 그 직선에 평행한 직선은 단 하나만 존재한다.[1]

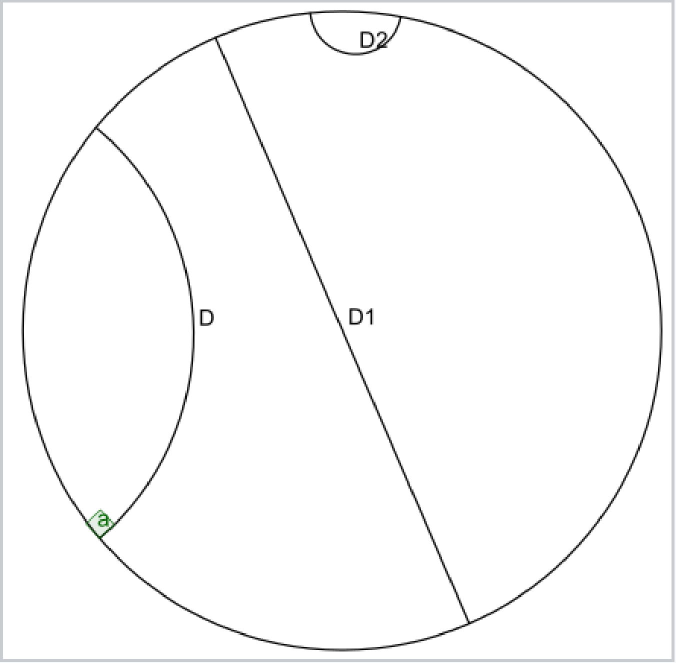




– Recap

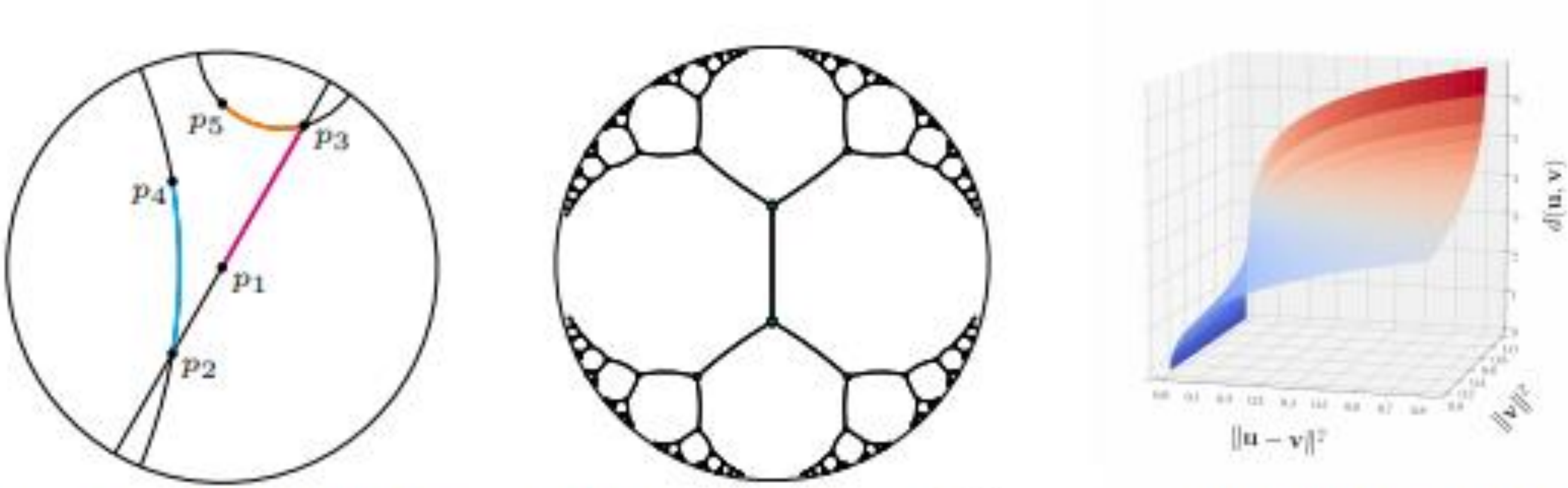


사진출처: wikipedia



Poincaré disk with 3 ultraparallel (hyperbolic) straight lines

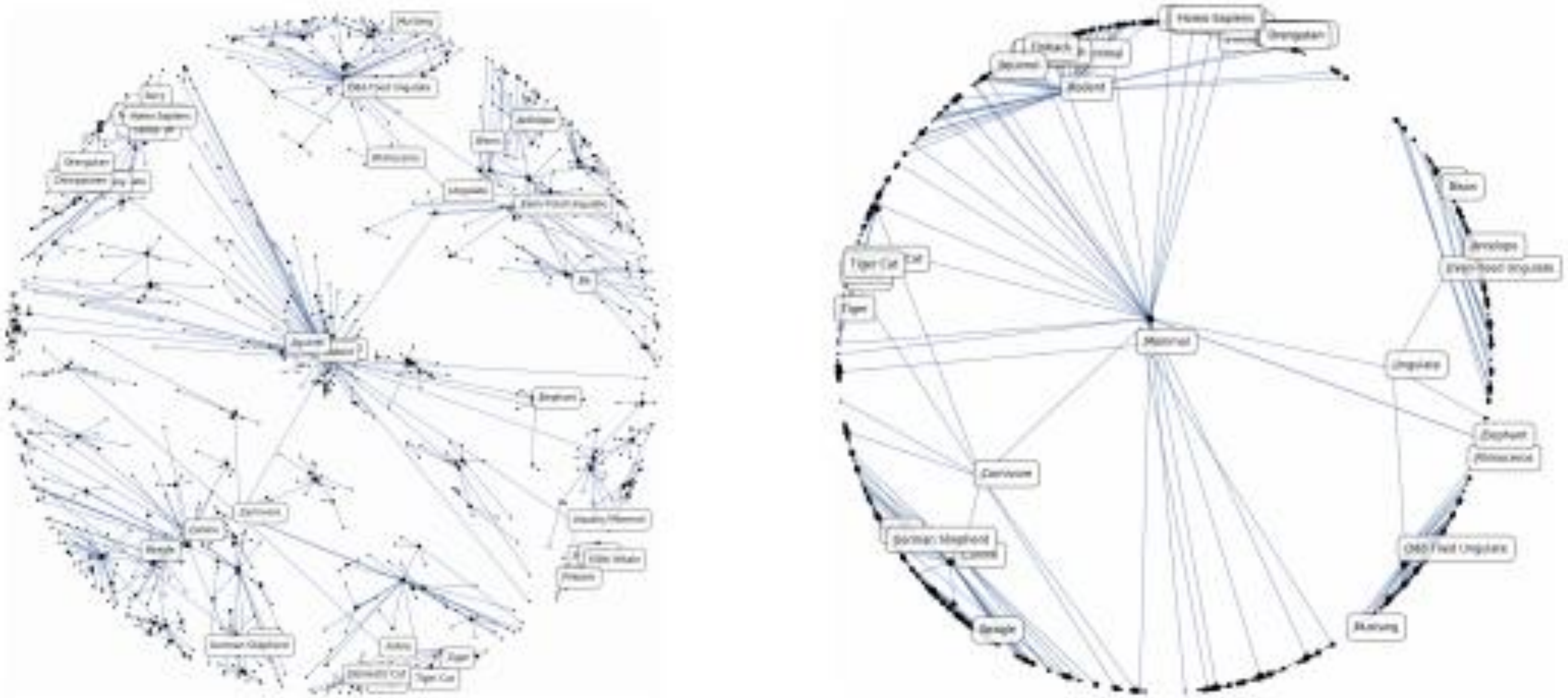
– Recap



(a) Geodesics of the Poincaré disk (b) Embedding of a tree in $\mathcal{B}^2$ (c) Growth of Poincaré distance

Figure 1: (a) Due to the negative curvature of $\mathcal{B}$, the distance of points increases exponentially (relative to their Euclidean distance) the closer they are to the boundary. (c) Growth of the Poincaré distance $d(\boldsymbol{u}, \boldsymbol{v})$ relative to the Euclidean distance and the norm of $\boldsymbol{v}$ (for fixed $\|\boldsymbol{u}\| = 0.9$). (b) Embedding of a regular tree in $\mathcal{B}^2$ such that all connected nodes are spaced equally far apart (i.e., all black line segments have identical hyperbolic length).

– Recap



(a) Intermediate embedding after 20 epochs (b) Embedding after convergence

Figure 2: Two-dimensional Poincaré embeddings of transitive closure of the WordNet mammals subtree. Ground-truth `is-a` relations of the original WordNet tree are indicated via blue edges. A Poincaré embedding with $d = 5$ achieves mean rank 1.26 and MAP 0.927 on this subtree.

– Hyperbolic spaces and their Cartesian product

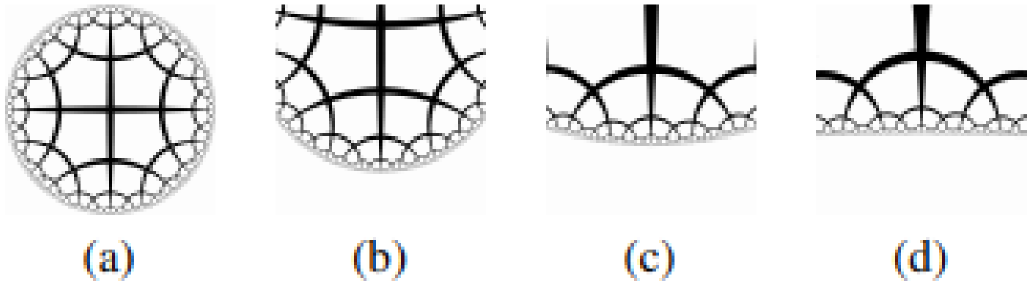


Figure 1: Isometric deformation φ of $\mathbb{D}^2$ into $\mathbb{H}^2$.

$$d_{\mathbb{D}^n}(x, y) = \cosh^{-1}\left(1 + \lambda_x \lambda_y \|x - y\|_2^2 / 2\right)$$

$$\lambda_x := 2/(1 - \|x\|_2^2)$$

$$d_{(\mathbb{D}^n)^p}(x, y)^2 = \sum_{i=1}^{p} d_{\mathbb{D}^n}(x_i, y_i)^2.$$

$$d_{\mathbb{H}^2}(x, y) = \cosh^{-1}\left(1 + \|x - y\|_2^2 / (2 y_1 y_2)\right)$$

– Adapting GloVe

$$X_i = \sum_k X_{ik};\ P_{ij} = X_{ij}/X_i$$

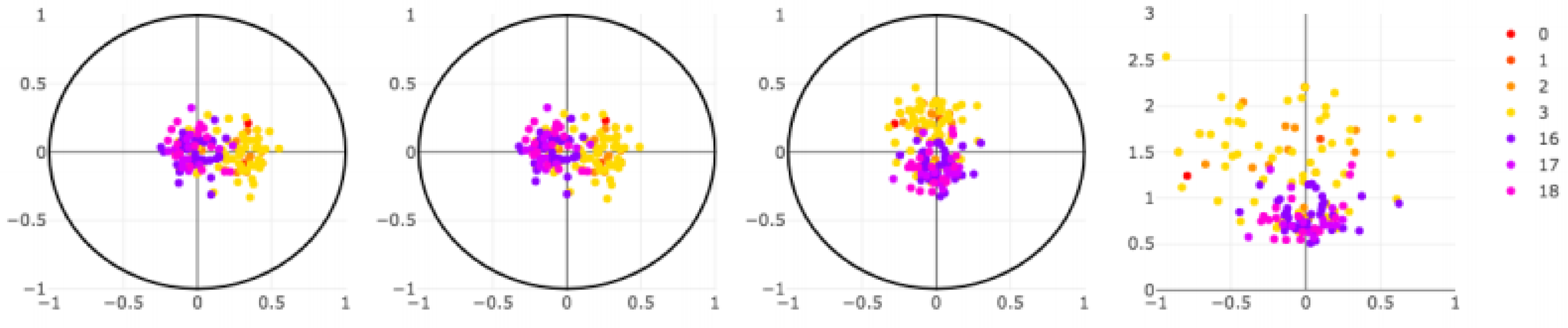
$$J = \sum_{i,j=1}^{V} f(X_{ij}) \left(w_i^T \tilde{w}_j + b_i + \tilde{b}_j - \log X_{ij} \right)^2 ,$$

$$J = \sum_{i,j=1}^{V} f(X_{ij}) \left(-h(d(w_i, \tilde{w}_j)) + b_i + \tilde{b}_j - \log X_{ij} \right)^2 ,$$

– Connecting Gaussian Embeddings & Hyperbolic Embeddings

$$d_F\left(\mathcal{N}(\mu,\sigma^2),\mathcal{N}(\mu',\sigma'^2)\right)=\sqrt{2}d_{\mathbb{H}^2}\left((\mu/\sqrt{2},\sigma),(\mu'/\sqrt{2},\sigma')\right).$$

$$d_F\left(\mathcal{N}(\mu,\Sigma),\mathcal{N}(\mu',\Sigma')\right)=\sqrt{\sum_{i=1}^{n}2d_{\mathbb{H}^2}\left((\mu_i/\sqrt{2},\sigma_i),(\mu_i'/\sqrt{2},\sigma_i')\right)^2}.$$


1
0.5
0
−0.5
−1
−1
−0.5
0
0.5
1
3
2.5
2
1.5
1
0.5
0
0
1
2
3
16
17
18