Adaptive Cannistraci-Hebb Network Automata Modelling of Complex Networks for Path-based Link Prediction

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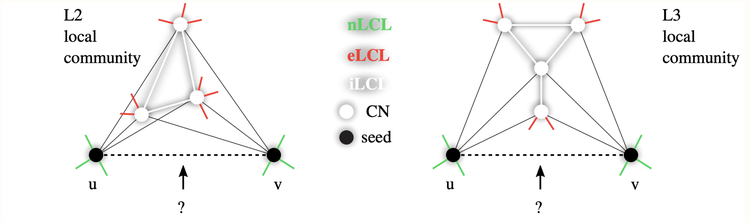
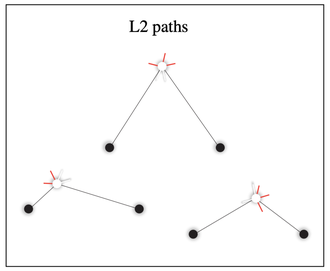
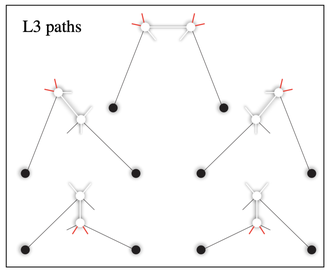
Cannistraci-Hebb (CH) Theory





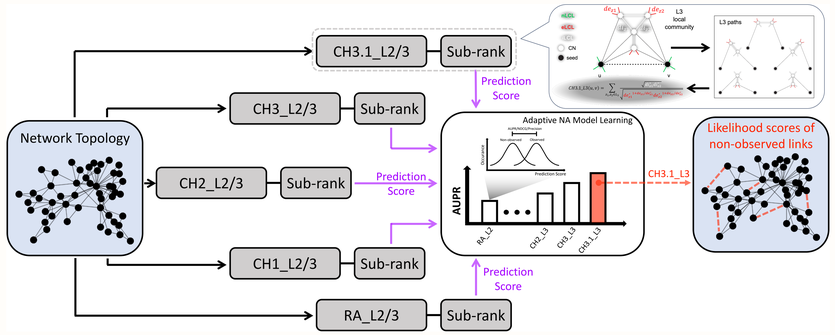


Model	$L2$	$L3$	Ln
RA	RA-L2$(u,v) = \sum_{z \in L_2} \frac{1}{d_z}$	RA-L3$(u,v) = \sum_{z_1,z_2 \in L_3} \frac{1}{\sqrt{d_{z_1} d_{z_2}}}$	RA-Ln$(u,v) = \sum_{z_1,\dots,z_{n-1} \in L_n} \frac{1}{\left(\prod_{k=1}^{n-1} d_{z_k}\right)^{1/(n-1)}}$
CH1	CH1-L2$(u,v) = \sum_{z \in L_2} \frac{di_z}{d_z}$	CH1-L3$(u,v) = \sum_{z_1,z_2 \in L_3} \frac{\sqrt{di_{z_1} di_{z_2}}}{\sqrt{d_{z_1} d_{z_2}}}$	CH1-Ln$(u,v) = \sum_{z_1,\dots,z_{n-1} \in L_n} \frac{\left(\prod_{k=1}^{n-1} di_{z_k}\right)^{1/(n-1)}}{\left(\prod_{k=1}^{n-1} d_{z_k}\right)^{1/(n-1)}}$
CH2	CH2-L2$(u,v) = \sum_{z \in L_2} \frac{di_z^*}{de_z^*}$	CH2-L3$(u,v) = \sum_{z_1,z_2 \in L_3} \frac{\sqrt{di_{z_1}^* di_{z_2}^*}}{\sqrt{de_{z_1}^* de_{z_2}^*}}$	CH2-Ln$(u,v) = \sum_{z_1,\dots,z_{n-1} \in L_n} \frac{\left(\prod_{k=1}^{n-1} di_{z_k}^*\right)^{1/(n-1)}}{\left(\prod_{k=1}^{n-1} de_{z_k}^*\right)^{1/(n-1)}}$
CH3	CH3-L2$(u,v) = \sum_{z \in L_2} \frac{1}{de_z^*}$	CH3-L3$(u,v) = \sum_{z_1,z_2 \in L_3} \frac{1}{\sqrt{de_{z_1}^* de_{z_2}^*}}$	CH3-Ln$(u,v) = \sum_{z_1,\dots,z_{n-1} \in L_n} \frac{1}{\left(\prod_{k=1}^{n-1} de_{z_k}^*\right)^{1/(n-1)}}$
CH3.1	CH3.1-L2$(u,v) = \sum_{z \in L_2} \frac{di_z^*}{de_z^{1+de_z/de_z^*}}$	CH3.1-L3$(u,v) = \sum_{z_1,z_2 \in L_3} \frac{\sqrt{di_{z_1}^* di_{z_2}^*}}{\sqrt{de_{z_1}^{*\,1+de_{z_1}/de_{z_1}^*} de_{z_2}^{*\,1+de_{z_2}/de_{z_2}^*}}}$	CH3.1-Ln$(u,v) = \sum_{z_1,\dots,z_{n-1} \in L_n} \frac{\left(\prod_{k=1}^{n-1} di_{z_k}^*\right)^{1/(n-1)}}{\left(\prod_{k=1}^{n-1} de_{z_k}^{*\,1+de_{z_k}/de_{z_k}^*}\right)^{1/(n-1)}}$

Two pillars:

- Minimization of external links within local communities.
- Path-based definition of local communities: homophilic (similarity-driven, L2) vs synergetic (diversity-driven, L3)

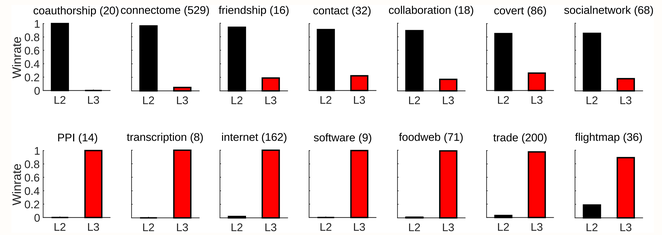
Cannistraci-Hebb Network Automata (CHA)



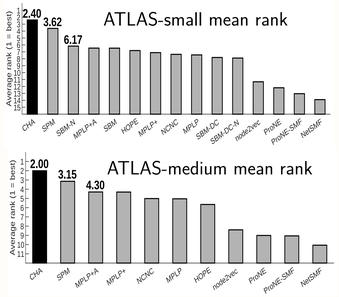
- **Adaptive model selection:** CHA automatically chooses the most suitable Cannistraci–Hebb rule (L2 vs. L3) for each network by evaluating how well candidate models separate observed from non-observed links.
- **Sub-ranking refinement:** When CH scores are tied, CHA refines predictions using a shortest-path–based proximity measure that compares node-pair topological similarity.

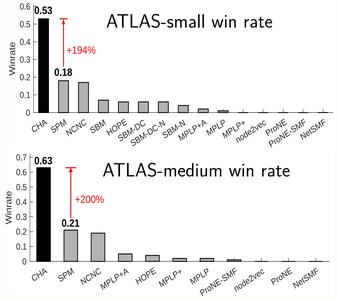
Link Prediction Algorithm	Field	Year	Networks Tested
SBM	Statistical Physics	2014	8
SBM-DC	Statistical Physics	2014	5
SBM-N, SBM-DC-N	Statistical Physics	2014	33
SPM	Quantum Physics	2015	13
HOPE	Computer Science	2016	4
node2vec	Computer Science	2016	3
ProNE, ProNE-SMF	Computer Science	2019	5
NetSMF	Computer Science	2019	5
MPLP, MPLP+	Computer Science	2024	15
CHA	**Physics & CS**	**2025**	**1283**

Experiments



L2 vs L3





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