GRADES-NDA 2019

Evaluation of the Context-Free Path Querying Algorithm Based on Matrix Multiplication

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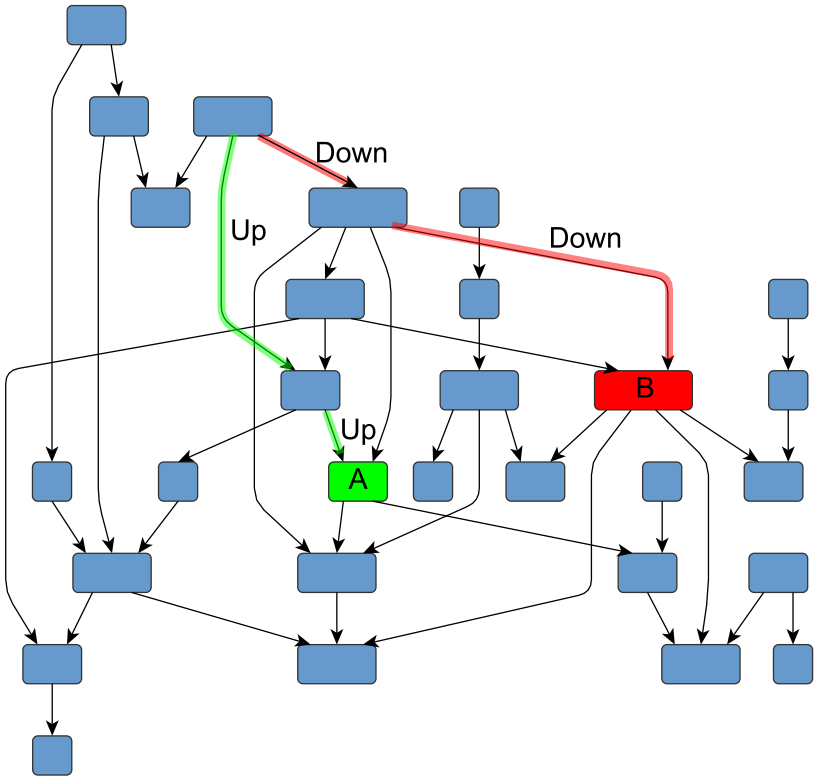
Context-Free Path Querying



Navigation through a graph

- Are nodes A and B on the same level of hierarchy?
- Is there a path of form $\mathbf{Up}^n\,\mathbf{Down}^n$?
- Find all paths of form $\mathbf{Up}^n\,\mathbf{Down}^n$ which start from the node A

Context-Free Path Querying: Relational Query Semantics

- $\mathbb{G} = (\Sigma, N, P)$ — context-free grammar in normal form
  - $A \to BC$, where $A, B, C \in N$
  - $A \to x$, where $A \in N, x \in \Sigma$
  - $L(\mathbb{G}, A) = \{\omega \mid A \to^* \omega\}$
- $G = (V, E, L)$ — directed graph
  - $v \xrightarrow{l} u \in E$
  - $L \subseteq \Sigma$
- $\omega(\pi) = \omega(v_0 \xrightarrow{l_0} v_1 \xrightarrow{l_1} \cdots \xrightarrow{l_{n-2}} v_{n-1} \xrightarrow{l_{n-1}} v_n) = l_0 l_1 \cdots l_{n-1}$
- $R_A = \{(n, m) \mid \exists n\pi m$, such that $\omega(\pi) \in L(\mathbb{G}, A)\}$

CPU-based implementations

[Scipy] Sparse matrices multiplication by using Scipy in Python programming language

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[M4RI] Dense matrices multiplication by using **m4ri2** library which implements the Method of Four Russians in **C** language

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[GPU_N] Our own implementation of the naïve boolean matrix multiplication in CUDA C with boolean values treated as bits and packed into uint_32.

[GPU_Py] Manual implementation of naïve boolean matrix multiplication in Python by using numba compiler. Boolean values are packed into uint_32.

Evaluation: worst case

#V	Scipy	M4RI	GPU4R	GPU_N	GPU_Py	CuSprs
16	0.032	< 1	0.008	0.002	0.027	0.309
32	0.118	0.001	0.034	0.008	0.136	0.441
64	0.476	0.041	0.133	0.032	0.524	0.988
128	2.194	0.226	0.562	0.129	2.751	3.470
256	15.299	1.994	3.088	0.544	11.883	15.317
512	121.287	23.204	13.685	2.499	43.563	102.269
1024	1593.284	528.521	88.064	19.357	217.326	1122.055
2048	-	-	-	325.174	-	-

Evaluation: sparse

Graph	Scipy	M4RI	GPU4R	GPU_N	GPU_Py	CuSprs
G5k-0.001	10.352	0.647	0.113	0.041	0.216	5.729
G10k-0.001	37.286	2.395	0.435	0.215	1.331	35.937
G10k-0.01	97.607	1.455	0.273	0.138	0.763	47.525
G10k-0.1	601.182	1.050	0.223	0.114	0.859	395.393
G20k-0.001	150.774	11.025	1.842	1.274	6.180	-
G40k-0.001	-	97.841	11.663	8.393	37.821	-
G80k-0.001	-	1142.959	88.366	65.886	-	-

Example 2: Pseudoknot

RDF			Query G_4					
Name	#V	#E	Scipy	M4RI	GPU4R	GPU_N	GPU_Py	CuSprs
atm-prim	291	685	3	2	2	1	5	269
biomed	341	711	3	5	2	1	5	283
foaf	256	815	2	9	2	< 1	5	270
funding	778	1480	4	7	4	1	5	279
generations	129	351	3	3	2	< 1	5	273
people_pets	337	834	3	3	3	1	7	284
pizza	671	2604	6	8	3	1	6	292
skos	144	323	2	4	2	< 1	5	273
travel	131	397	3	5	2	< 1	6	268
unv-bnch	179	413	2	4	2	< 1	5	266
wine	733	2450	7	6	4	1	7	294

RDF			Query G_5					
Name	#V	#E	Scipy	M4RI	GPU4R	GPU_N	GPU_Py	CuSprs
atm-prim	291	685	1	< 1	1	< 1	2	267
biomed	341	711	4	< 1	1	< 1	5	280
foaf	256	815	1	< 1	1	< 1	2	263
funding	778	1480	2	< 1	3	< 1	4	274
generations	129	351	1	< 1	1	< 1	2	263
people_pets	337	834	1	< 1	1	< 1	3	277
pizza	671	2604	2	< 1	2	< 1	5	278
skos	144	323	< 1	< 1	1	< 1	2	265
travel	131	397	1	< 1	1	< 1	3	271
unv-bnch	179	413	1	< 1	1	< 1	3	266
wine	733	2450	1	< 1	3	< 1	3	281

Example 2: Pseudoknot

RDF			Query G_5					
Name	#V	#E	Scipy	M4RI	GPU4R	GPU_N	GPU_Py	CuSprs
atm-prim	291	685	1	< 1	1	< 1	2	267
biomed	341	711	4	< 1	1	< 1	5	280
foaf	256	815	1	< 1	1	< 1	2	263
funding	778	1480	2	< 1	3	< 1	4	274
generations	129	351	1	< 1	1	< 1	2	263
people_pets	337	834	1	< 1	1	< 1	3	277
pizza	671	2604	2	< 1	2	< 1	5	278
skos	144	323	< 1	< 1	1	< 1	2	265
travel	131	397	1	< 1	1	< 1	3	271
unv-bnch	179	413	1	< 1	1	< 1	3	266
wine	733	2450	1	< 1	3	< 1	3	281

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- Trained models: https://github.com/YaccConstructor/YC.Bio

Thanks!