

# Complex Networks Homework 2

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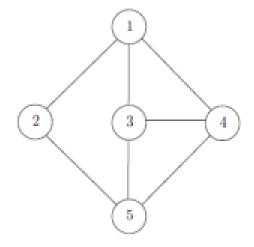
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## 2 Exercise 2

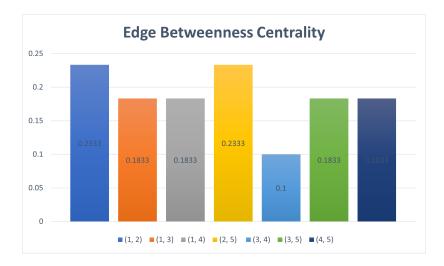
The Shortest-Path Node Betweenness centrality ci of nodes and edges of a network are related as follows:

$$C_B(i) = \sum_{i < l} \frac{g_{il}(i)}{g_{il}} = \frac{1}{2} \sum_{i < l} a_{il} \frac{g_{il}(e)}{g_{il}} \Rightarrow$$

$$C_B(i) = \frac{1}{2} \sum_{i < l} a_{il} \frac{g_{il}(e)}{g_{il}} - 2(N - 1) = \frac{1}{2} \sum_{l=1} a_{il} C_B(e_i l) - 2(N - 1)$$



The Edge Betweenness Centrality of each edge from above is:

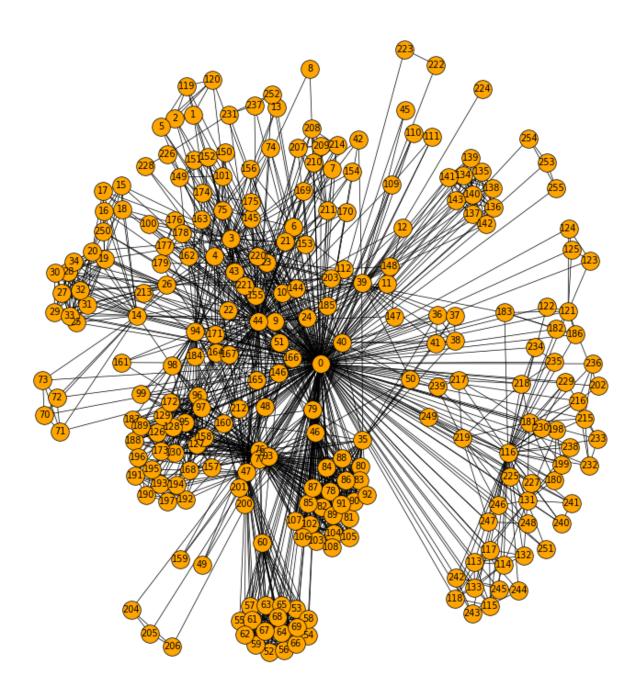


Calculating the sortest paths of each node:

- Node 1: 1: [1], 2: [1, 2], 3: [1, 3], 4: [1, 4], 5: [1, 2, 5]
- Node 2: 2: [2], 1: [2, 1], 5: [2, 5], 3: [2, 1, 3], 4: [2, 1, 4]
- $\bullet \ \ \mathbf{Node} \ \ \mathbf{3} \text{:} \ \ [3], \ 1 \text{:} \ [3, \ 1], \ 4 \text{:} \ [3, \ 4], \ 5 \text{:} \ [3, \ 5], \ 2 \text{:} \ [3, \ 1, \ 2]$
- Node 4: 4: [4], 1: [4, 1], 3: [4, 3], 5: [4, 5], 2: [4, 1, 2]
- Node 5: 5: [5], 2: [5, 2], 3: [5, 3], 4: [5, 4], 1: [5, 2, 1]

# 4 Graph

## 4.1 Authors and Co-authors Graph



## 4.2 Node index and author's name

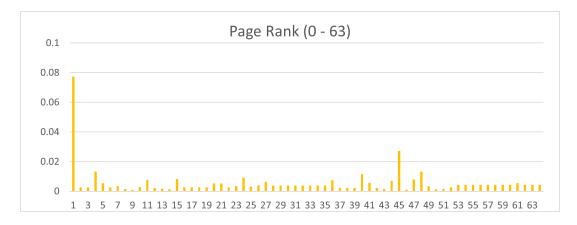
0		-					
	Thanasis Korakis	65	Alexandros G. Fragkiadaki	130	Eduard Escalona	197	Henrik Lundgren
1	Valentina Nejkovic	66	Pavlos Charalampidis	131	Pei Liu 0001	198	Francesco Verde
2	Filip Jelenkovic	67	Nicolas Seydoux	132	Theodore S. Rappaport	199	Anna Scaglione
3	Nikos Makris	68	Christelle Ecrepont	133	Parisa Amiri-Eliasi	200	George Parisis
4	Virgilios Passas	69	Mengxuan Zhao	134	Hyunwoo Lee 0001	201	Dirk Trossen
5	Milorad Tosic	70	Emmanouil Pissadakis	135	Donghyun Kim	202	Chen Dong
6	Christos Zarafetas	71	Nikolaos Alachiotis	136	Junho Suh	203	Maximilian Ott
7	Alexandros Valantasis	72	Dimitris Theodoropoulos	137	Ted Taekyoung Kwon	204	Hongbin Li
8	Theodoros Tsourdinis	73	Dionisios N. Pnevmatikato	138	Pedro Martinez-Julia Antonio F. Skarmeta	205	Phuoc Tran-Gia
9	Panagiotis Tzimotoudis	74	Pavlos Basaras	140	Taewan You	206	Hong-Shik Park
10	Giannis Kazdaridis	75	Navid Nikaein	141	Loic Baron	207	Giovanni Di Stasi
11	Nikos Sidiropoulos	76	Anna Tzanakaki	142	Serge Fdida	208	Roberto Bifulco
12	Ioannis Zografopoulos	77	Markos P. Anastasopoulos	143	JongWon Kim	209	Stefano Avallone
13	Christos Nanis	78	Ignacio Berberana	144	Harris Niavis	210	Roberto Canonico
14	Panagiotis Skrimponis	79	Dimitris Syrivelis	145	Ioannis Igoumenos	211	Nikolaos Giallelis
15	Sheila Borges Rajguru	80	Ilker Demirkol	146	Max Ott	212	Adamantios Fiamegkos
16	Karen Cheng	81	Jesús Gutlérrez Terán	147	Dimosthenis Delimpasis	213	Georgios Kyriakou
17	Jonatan Ostrometzky	82	Eckhard Grass	148	Konstantinos Chounos	214	Francesco Paolo D'Elia
18	Emily Ford	83	Qing Wei 0001	149	Eryk Schiller	215	Özgü Alay
19	Zoran Kostic	84	Emmanouil Pateromichela	150	Islam Alyafawi	216	Yao Wang 0001
20	Gil Zussman	85	Nikola Vucic	151	Zhongliang Zhao	217	Feilu Liu
21	Vasileios Miliotis	86	Albrecht J. Fehske	152	Torsten Braun	218	Jian Lin
22	Kostas Chounos	87	Michael Grieger	153	Vasilis Maglogiannis	219	Zhifeng Tao
		88	Michael Eiselt	154	Dries Naudts	220	Angelos-Christos G. Anadi
23	Apostolos Apostolaras	89	Jens Bartelt	155	Ingrid Moerman	221	Luis Rodriguez
24	Polychronis Symeonidis	90	Gerhard P. Fettweis	156	Spyros Kechagias	222	Giovanni Pau 0001
25	Dipankar Raychaudhuri	91	George L. Lyberopoulos	157	Yi Shu	223	Ryuji Wakikawa
26	Ivan Seskar	92	Eleni Theodoropoulou	158	Georgios Zervas	224	Sung-Ju Lee
27	Dan Kilper	93	Dimitra Simeonidou	159	Constantine Dovrolis	225	Michael E. Knox
28	Tingjun Chen	94	Kostas Katsalis	160	Vasilis Sourlas	226	George Athanasiou
29	Jakub Kolodziejski	95	Bijan Rahimzadeh Rofoee	161	Thanasis Papapioannou	227	Shashi Raj Singh
30	Michael Sherman	96	Giada Landi	162	Raymond Knopp	228	Özgür Erçetin
31	Xiaoxiong Gu	97	Jordi Ferrer Riera	163	Antonio Maria Cipriano	229	Ozgu Alay
22	Harish Krishnaswamy		and the same of th				
32	rialish Krishilaswaniy	98	Kostas Kousias	164	Iordanis Koutsopoulos	230	Yao Wang
32	Sumit Maheshwari	98	L Kiraly	164 165	Thierry Rakotoarivelo		
	Sumit Maheshwari Craig Gutterman		-p-interpretation	165 166	Thierry Rakotoarivelo Thierry Parmentelat	231	Ioannis Broustis
33	Sumit Maheshwari	99	L. Kiraly	165	Thierry Rakotoarivelo		
33 34	Sumit Maheshwari Craig Gutterman Daniel Camps-Mur Ferran Cañellas	99 100	L. Kiraly Agorastos Dimitrios Sama	165 166 167 168	Thierry Rakotoarivelo Thierry Parmentelat Giannis Igoumenos Joan Antoni García Espín	231	Ioannis Broustis
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33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48	Sumit Maheshwari Craig Gutterman Daniel Camps-Mur Ferran Cañellas Azahar Machwe Jorge Paracuellos Kostas Choumas Dimitris Giatsios Hadi Razzaghi Kouchaksarae Panagiotis Karamichailidis Donatos Stavropoulos Leandros Tassiulas Marios Karatisoglou Paris Flegkas Stratos Keranidis Ilias Syrigos	99 100 101 102 103 104 105 106 107 108 109 110 111 112	L. Kiraly Agorastos Dimitrios Sama Romain Favraud Nebojsa Maletic Eduard Garcia Villegas Vaia Kalokidou Peter Legg Dusan Markovic Jay Kant Chaudhary Jim Zou Georgios S. Paschos Chih-Ping Li Eytan H. Modiano George losifidis	165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180	Thierry Rakotoarivelo Thierry Parmentelat Giannis Igoumenos Joan Antoni García Espín Spyros Lalis Stavros Ioannidis 0002 Wei Liu 0019 Y. Yan Joan A. García-Espin Katerina Pechlivanidou Dimitrios Katsaros 0001 Mahmoud Hadef Jim O'Reilly Alain Mourad Belkacem Mouhouche Chun Nie	231 232 233 234 235 236 237 238 239 240 241 242	Ioannis Broustis Caleb Li Anurag Rai Xiao Wang Shunyuan Ye Zhe Xu Gentian Jakllari Yuanpeng Liu Jinyun Zhang Ankit Sharma Vikas Gelara Kaustubh Sinkar
33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49	Sumit Maheshwari Craig Gutterman Daniel Camps-Mur Ferran Cañellas Azahar Machwe Jorge Paracuellos Kostas Choumas Dimitris Giatsios Hadi Razzaghi Kouchaksarae Panagiotis Karamichailidis Donatos Stavropoulos Leandros Tassiulas Marios Karatisoglou Paris Flegkas Stratos Keranidis Ilias Syrigos Nikos Sakellariou	99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114	L. Kiraly Agorastos Dimitrios Sama Romain Favraud Nebojsa Maletic Eduard Garcia Villegas Vaia Kalokidou Peter Legg Dusan Markovic Jay Kant Chaudhary Jim Zou Georgios S. Paschos Chih-Ping Li Eytan H. Modiano George losifidis C. Nicolas Barati S. Amir Hosseini	165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181	Thierry Rakotoarivelo Thierry Parmentelat Giannis Igoumenos Joan Antoni Garcia Espín Spyros Lalis Stavros Ioannidis 0002 Wei Liu 0019 Y. Yan Joan A. Garcia-Espin Katerina Pechlivanidou Dimitrios Katsaros 0001 Mahmoud Hadef Jim O'Reilly Alain Mourad Belkacem Mouhouche Chun Nie Elza Erkip	231 232 233 234 235 236 237 238 239 240 241 242 243	Ioannis Broustis Caleb Li Anurag Rai Xiao Wang Shunyuan Ye Zhe Xu Gentian Jakllari Yuanpeng Liu Jinyun Zhang Ankit Sharma Vikas Gelara Kaustubh Sinkar Amit Jagirdar
33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50	Sumit Maheshwari Craig Gutterman Daniel Camps-Mur Ferran Cañellas Azahar Machwe Jorge Paracuellos Kostas Choumas Dimitris Giatsios Hadi Razzaghi Kouchaksarae Panagiotis Karamichailidis Donatos Stavropoulos Leandros Tassiulas Marios Karatisoglou Paris Flegkas Stratos Keranidis Ilias Syrigos Nikos Sakellariou Joan Josep Aleixendri Cruel	99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115	L. Kiraly Agorastos Dimitrios Sama Romain Favraud Nebojsa Maletic Eduard Garcia Villegas Vaia Kalokidou Peter Legg Dusan Markovic Jay Kant Chaudhary Jim Zou Georgios S. Paschos Chih-Ping Li Eytan H. Modiano George Iosifidis C. Nicolas Barati S. Amir Hosseini Marco Mezzavilla	165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182	Thierry Rakotoarivelo Thierry Parmentelat Giannis Igoumenos Joan Antoni Garcia Espín Spyros Lalis Stavros Ioannidis 0002 Wei Liu 0019 Y. Yan Joan A. Garcia-Espin Katerina Pechlivanidou Dimitrios Katsaros 0001 Mahmoud Hadef Jim O'Reilly Alain Mourad Belkacem Mouhouche Chun Nie Elza Erkip Cong Wang 0014	231 232 233 234 235 236 237 238 239 240 241 242 243 244	Ioannis Broustis Caleb Li Anurag Rai Xiao Wang Shunyuan Ye Zhe Xu Gentian Jakllari Yuanpeng Liu Jinyun Zhang Ankit Sharma Vikas Gelara Kaustubh Sinkar Amit Jagirdar Hang Liu
33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51	Sumit Maheshwari Craig Gutterman Daniel Camps-Mur Ferran Cañellas Azahar Machwe Jorge Paracuellos Kostas Choumas Dimitris Giatsios Hadi Razzaghi Kouchaksarae Panagiotis Karamichailidis Donatos Stavropoulos Leandros Tassiulas Marios Karatisoglou Paris Flegkas Stratos Keranidis Ilias Syrigos Nikos Sakellariou Joan Josep Aleixendri Cruel Ioannis Zographopoulos	99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116	L. Kiraly Agorastos Dimitrios Sama Romain Favraud Nebojsa Maletic Eduard Garcia Villegas Vaia Kalokidou Peter Legg Dusan Markovic Jay Kant Chaudhary Jim Zou Georgios S. Paschos Chih-Ping Li Eytan H. Modiano George losifidis C. Nicolas Barati S. Amir Hosseini Marco Mezzavilla Shivendra S. Panwar	165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183	Thierry Rakotoarivelo Thierry Parmentelat Giannis Igoumenos Joan Antoni Garcia Espín Spyros Lalis Stavros Ioannidis 0002 Wei Liu 0019 Y. Yan Joan A. Garcia-Espin Katerina Pechlivanidou Dimitrios Katsaros 0001 Mahmoud Hadef Jim O'Reilly Alain Mourad Belkacem Mouhouche Chun Nie Elza Erkip Cong Wang 0014 Michael Zink	231 232 233 234 235 236 237 238 239 240 241 242 243	Ioannis Broustis Caleb Li Anurag Rai Xiao Wang Shunyuan Ye Zhe Xu Gentian Jakllari Yuanpeng Liu Jinyun Zhang Ankit Sharma Vikas Gelara Kaustubh Sinkar Amit Jagirdar
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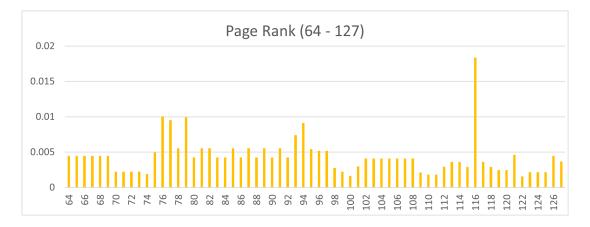
To calculate the nearest-neighbor edge centrality used a python script (4.py) But because the solution is too large, the solution is on exec4.xlsx

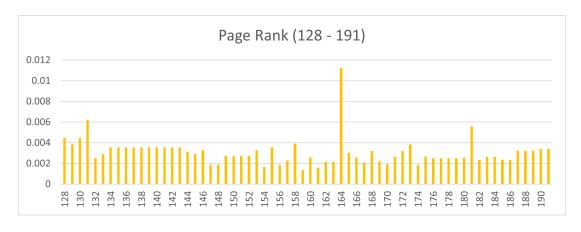
$$DC(e = (a, b)) = \frac{DC(a) - DC(b) - 2}{|DC(a) - DC(b)| + 1}$$

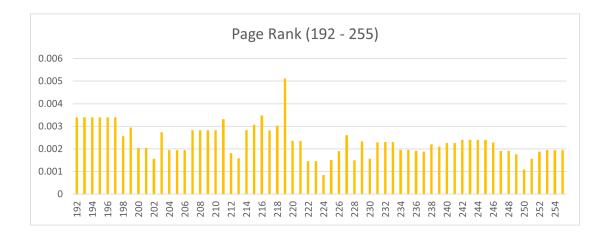
#### 6 Exercise 5

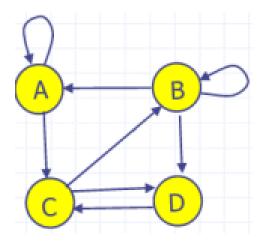
The Page Rank of the Author-Co authors directive graph of Thanasis Korakis is:











We do not take into account of damping factor because the Graph is:

- Stochastic
- Irreducible
- Aperiodic

And solving the following system, we pass the following results:

$$x_A = \frac{x_A}{2} + \frac{x_B}{3}$$
 (1)

$$x_B = \frac{x_B}{3} + \frac{x_C}{2} \tag{2}$$

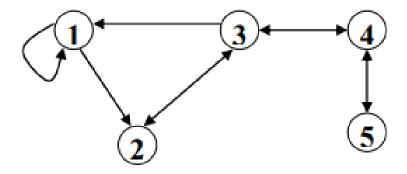
$$x_C = \frac{x_A}{2} + x_D \tag{3}$$

$$x_D = \frac{x_B}{3} + \frac{x_C}{2} \tag{4}$$

$$x_A + x_B + x_C + x_D = 1 (5)$$

Solution:

$$x_A = 0.16, x_B = 0.25, x_C = 0.33, x_B = 0.25$$



The Page Rank for a different damping factor of the above Graph is:

