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Preface

This volume, Proceedings of The 15th International Symposium on Operations Research, called SOR'19, contains papers presented at SOR'19 (http://sor19.fov.uni-mb.si/) that was organized by Slovenian Society INFORMATIKA (SDI), Section for Operations Research (SOR), University of Maribor, Faculty of Organizational Sciences, Kranj, Slovenia, and University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia, held in Bled, Slovenia, from September 25 to September 27, 2019. The volume contains blindly reviewed papers or abstracts of talks presented at the symposium.

The opening address at SOR'19 was given by Prof. Dr. Lidija Zadnik Stirn, President of the Slovenian Section of Operations Research, Mr. Niko Schlamberger, President of the Slovenian Society Informatika, Prof. Dr. Iztok Podbregar, Dean of the Faculty of Organizational Sciences, University of Maribor, Prof. Dr. Mitjan Kalin, Dean of the Faculty of Mechanical Engineering, University of Ljubljana, Prof. Dr. Immanuel Bomze, President of The Association of European Operational Research Societies (EURO),), Prof. Dr. Zrinka Lukać, President of Croatian Operational Research Society (CRORS), and presidents/representatives of some others Operations Research Societies from abroad.

SOR'19 is the scientific event in the area of operations research, another one in the traditional series of the biannual international OR conferences, organized in Slovenia by SDI-SOR. It is a continuity of fourteen previous symposia. The main objective of SOR'19 is to advance knowledge, interest and education in OR in Slovenia, in Europe and worldwide in order to build the intellectual and social capital that are essential in maintaining the identity of OR, especially at a time when interdisciplinary collaboration is proclaimed as significantly important in resolving problems facing the current challenging times. Further, by joining IFORS and EURO, the SDI-SOR agreed to work together with diverse disciplines, i.e. to balance the depth of theoretical knowledge in OR and the understanding of theory, methods and problems in other areas within and beyond OR. We believe that SOR'19 creates the advantage of these objectives, contributes to the quality and reputation of OR by presenting and exchanging new developments, opinions, experiences in the OR theory and practice.

SOR'19 was highlighted by five distinguished keynote speakers. The first part of the Proceedings SOR'19 comprises invited abstracts and papers, presented by five outstanding scientists: Acad. Prof. Dr. Ivan Bratko, Faculty of Computer and Information Science, University of Ljubljana, Ljubljana, Slovenia, Prof. Dr. Mirjana Čižmešija, University of Zagreb, Faculty of Economics and Business, Zagreb, Croatia, Assoc. Prof. Dr. Tibor Illés, Budapest University of Technology and Economics, Institute of Mathematics, Budapest, Hungary, Prof. Dr. Joanna Józefowska, Poznan University of Technology, Poznan, Poland (the EURO plenary), and Prof. Dr. Matej Praprotnik, Laboratory for Molecular Modeling, National Institute of Chemistry, Ljubljana, Slovenia.

Proceedings includes 106 papers or abstracts written by 203 authors. Most of the authors of the contributed papers came from Slovenia (79), then from Croatia (43), Czech Republic (13), Hungary (12), Slovak Republic (12), Poland (9), Austria (7), Spain (5), France (4), Netherlands (3), Portugal (3), Italy (2), Norway (2), Romania (2), Thailand (2), Germany (1), Indonesia (1), Ireland (1), Serbia (1), and United Kingdom (1). The papers published in the Proceedings are divided into Plenary Lectures (5 abstracts), seven special sessions: Application of Operation Research in Agriculture and Agribusiness Management (5 papers), Formal and Behavioral Issues in MCDM (6 papers and 1 abstract), Graph Theory and

Algorithms (11 papers and 1 abstract), High-Performance Computing and Big Data (4 papers), Optimization in Human Environments (7 papers), System Modelling & Soft Operational Research (5 papers), Towards Industry 4.0 (5 papers), and eight sessions: Econometric Models and Statistics (10 papers), Environment and Social Issues (5 papers and 1 abstract), Finance and Investments (11 papers), Location and Transport, Graphs and their Applications (4 papers), Mathematical Programming and Optimization (7 papers and 2 abstracts), Multi-Criteria Decision-Making (6 papers), Human Resources (4 papers), and Production and Management (6 papers).

The Proceedings of the previous fourteen International Symposia on Operations Research organized by the Slovenian Section of Operations Research, that are listed at https://www.drustvo-informatika.si/sekcije/sor/sor-publikacijepublications/, are indexed in the following secondary and tertiary publications: Current Mathematical Publications, Mathematical Review, Zentralblatt fuer Mathematik/Mathematics Abstracts, MATH on STN International and CompactMath, INSPEC. The Proceedings SOR'19 are expected to be covered by the same bibliographic databases.

The success of the scientific events at SOR'19 and the present proceedings should be seen as a result of joint effort. On behalf of the organizers we would like to express our sincere thanks to all who have supported us in preparing the event. We would not have succeeded in attracting so many distinguished speakers from all over the world without the engagement and the advice of active members of the Slovenian Section of Operations Research. Many thanks to them. Further, we would like to express our deepest gratitude to prominent keynote speakers, to the members of the Program and Organizing Committees, to the referees who raised the quality of the SOR'19 by their useful suggestions, section's chairs, and to all the numerous people - far too many to be listed here individually - who helped in carrying out The 15th International Symposium on Operations Research SOR'19 and in putting together these Proceedings. Last but not least, we appreciate the authors' efforts in preparing and presenting the papers, which made The 15th Symposium on Operations Research SOR'19 successful.

We would like to express a special gratitude to The Partnership for Advanced Computing in Europe (PRACE) for a financial support and to The Association of European Operational Research Societies (EURO) for financing the EURO plenary speaker.

Bled, September 25, 2019

Lidija Zadnik Stirn
Mirjana Kljajić Borštnar
Janez Žerovnik
Samo Drobne
Janez Povh
(Editors)

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MINIMIZING HUMAN STRESS IN SOCIAL NETWORKS WITH TARGETED INTERVENTIONS

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Abstract: Chronic stress in humans can substantially impair functioning of organizations. As stress can spread through social networks, psychosocial interventions targeted at the most contagious people can efficiently improve organizational functioning. On the example of employees working in healthcare institutions, we show how optimization methods based on network science can guide efficient decisions to minimize human stress.

Keywords: human stress, social networks, network science, social contagion, infection model

1 INTRODUCTION

There are good reasons why stress is sometimes dubbed a silent killer; often, we are not aware of its harmful effects until it is too late. From debilitating depression to potentially fatal cardiovascular disorders, it seems like harmful effects of stress have no boundaries. Stress has even been implicated as a causal factor in cancer [3]. In this day and age, it is difficult to avoid stressful situations. We are in daily contact with stressors emerging from the environment (e.g., noise), our habits and behaviour (e.g., sleep deprivation), and the social domain (e.g., stress in the workplace).

Among the myriad of possible instigators of stress, we argue that social factors can be particularly risky. Social connections have been crucial for survival throughout the human (evolutionary) history and relationships within our families, friendships, schools, and companies are at the centre of our everyday life. It comes as no surprise that people are remarkably sensitive to social affairs; up to a point that the emotions and behaviours of one person can directly trigger similar emotions and behaviours in others [6]. While both positive and negative emotions and behaviours can spread, humans have quicker and stronger reactions towards negative stimuli. Because stress is manifested in increased unpleasant emotions (e.g., anger) and inappropriate behavioural tendencies (e.g., hostility) [9], it can spread through social interactions and decrease overall human wellbeing in any social system, including work organizations.

From the perspective of an organization, mitigating human stress typically means deploying a psychosocial intervention, such as a stress management workshop. While this approach is reasonable, companies might be reluctant to cover sizeable costs needed to provide the intervention to all employees. Even if that is not the case, their money might be better spent in providing in-depth interventions for a selected group of people instead of addressing all employees superficially. Considerably decreasing stress levels in the *most contagious* employees may mitigate stress in the entire personnel to a greater extent than slightly reducing stress in *all* employees.

Employees that will spread stress-related emotions and behaviours more readily than others will generally have more social connections and experience greater levels of stress (e.g., certain managers). Psychosocial interventions aimed directly at them might be the most efficient approach to improve the overall well-being in the workplace. Network science is an efficient tool to model the structure and the connections between any group of entities, such as companies, groups, or individuals. With this, it serves as a basis to model the infection process, in our case, the spreading of stress between people. The objective of the paper is to show how optimization methods based on network science can improve the human environment. We will demonstrate this by running network infection simulations that can provide the information on the most efficient targets (people) for stress-reducing interventions.

2 METHOD

We collected data on stress and wellbeing of nursing home personnel. The data was used to create a network representing connections between employees, employee stress levels, and the probability of stress levels to spread among employees. To model the spread of the stress between the employees, we used the Generalized Independent Cascade model in which the connection strength and the initial stress level of each employee can be simulated [1]. The most emotionally contagious employee set (and consequently the most suitable targets for stress-reducing interventions) can be computed by infection maximization [7], where the objective function minimizes the global stress level of the network. The detailed procedure is presented below.

2.1 Data collection and transformation

414 employees from 14 nursing homes in Norway completed the survey collecting demographic data, work-related information (e.g., working hours, shift work), and levels of stress and well-being. From the data, we created a network with the nodes representing employees and their overall stress levels. (Stress levels were rescaled to values between 0 and 0.8.) Connections (i.e., edges) between them were assigned if 1) they were employed at the same nursing home, 2) had the same occupation (e.g., nurse), and 3) the age difference between them was not greater than 20 years. Edge weights were higher when employees were closer in age, had matching work shifts, and worked more hours overall. (The edge weights were rescaled to values between 0 and 0.6). Employees with the missing relevant data were excluded from the study. The resulting network had 289 nodes and 731 edges.

2.2 Infection Model

The basic idea of infection models is to simulate the spread of a virus, information, or any other entity in a network. The concept was proposed by Domingos and Richardson [4] and by Granovetter [5]. Originally, it was used to improve the efficiency of viral marketing. The mathematical model of the problem was later introduced to networks by Kempe et. al. [7, 8]. In the Independent Cascade Model, the strength of the connections is given by probabilities between $\mathbf{0}$ and $\mathbf{1}$, expressing the chance of the infection or the effect spreading across the connection.

To define the model, let $\boldsymbol{G(V,E)}$ be the network, where $\boldsymbol{V}$ is the set of the nodes and $\boldsymbol{E}$ describes the set of the edges. Let $\mathbf{0} \le \boldsymbol{p_{v_1,v_2}} \le \mathbf{0}$ be the edge probability between $\boldsymbol{v_1}$ and $\boldsymbol{v_2}$, where $\boldsymbol{v_1, v_2 \in V}$. To represent employee connections and stress spreading in the workplace, we used an extended Generalized Independent Cascade model [1]. The model defines probabilities on the nodes, so we define $\mathbf{0} \le \boldsymbol{s_v} \le \mathbf{1}$ as the stress level of the node $\boldsymbol{v}$. Described from the real-life viewpoint, the probability on the node states the chance of a person becoming infectious and spreading stress to other individuals.

If the network is given with the edge and node probabilities, let $\boldsymbol{f_v}$ be the final infection of the node $\boldsymbol{v}$ and the expected value $\boldsymbol{\sigma(V)}$ the sum of the final infection for each node. The final infection of the given $\boldsymbol{V}$ graph was computed by the Edge Simulation [1]. Chen et. al. [2] have proven that the simulation process is P#-complete, but the simulation can reach any precision level [7]. The code of the simulation was changed in the following way.

Algorithm 1: Edge Simulation in Generalized Independent Cascade

Input: G network, sample size k
$j = 0$
for all $v \in V : f_v = 0$
while $j < k$
  for all $e \in E$: set the state of the edge to active or passive based on p_e
  s=1
  Modified DFS from all $v \in V$
    $s = s(1 - p_u)$ where p_u is the stress level of the u visited node
  $f_v = f_v + 1 - s$
  $j = j + 1$
end while
for all $v \in V: f_v = \frac{f_v}{k}$

The simulation was used to compute the final stress level in one scenario. To choose the employees for the intervention, let $\boldsymbol{s_v^{intervention}}$ be the stress level of the node $\boldsymbol{v}$ after the stress-reducing intervention. If the stress of the person is decreased, we can rerun the simulation with the new stress levels, and the global infection of the network (and the overall stress levels) will also be decreased. In the case of a stress-reducing intervention, the model will decrease the stress level of a chosen employee and their local neighborhood, since this person will now have a lower probability to spread stress. If $\boldsymbol{\sigma(V)}$ is the expected value of the reference simulation and $\boldsymbol{I}$ is the set of the targeted employees, let $\boldsymbol{\sigma(V)_I}$ be the expected final infection value of the simulation in which the initial stress levels of the employees in the set $\boldsymbol{I}$ are changed from $\boldsymbol{s}$ to $\boldsymbol{s^{intervention}}$.

In the infection maximization problem, the main objective is to maximize the spread with an initial infector set. The original infection maximization problem was published by Kempe et. al [7], where they have proven the NP-hardness of the problem. The most efficient method to maximize the spread through a network is a greedy method, which can give 63% of the optimum in any case. The objective function maximizes the difference between the expected value of the initial reference simulation and in every iteration chooses the employee that minimizes the global stress level of the network (i.e., the employee undergoing a hypothetical stress-reducing intervention). A similar maximization problem was proposed in the following article [10]. The greedy method is the following:

Algorithm 2: Greedy Method to minimize the stress level of the employees

Input: G network
Output: Ordering of the employees based on stress reducing potential
$I = \emptyset$
while $|\mathbf{I}| \neq |V|$
  $I = I \cup \arg\max_{v \in G(V) \setminus I} (\sigma(V) - \sigma(V)_I)$

From a real-world point of view, the objective function that maximizes the difference between the different final infection values will minimize the global stress levels in our network. To show the optimal number of the hypothetically treated employees, it's possible to find the threshold where the global stress level will stop decreasing significantly.

3 RESULTS

A sample of the network is presented in Figure 1. Nodes are coloured based on the stress level of each employee and the width of the edges increases with the edge weight (i.e., probability of emotional (stress) contagion).

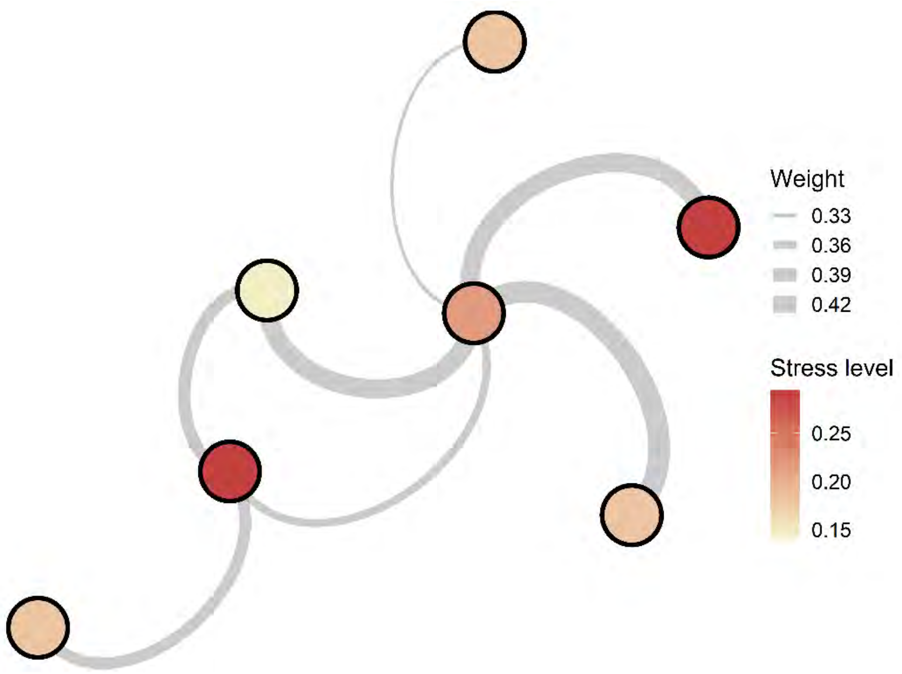

Figure 1: A sample of the network

In the network, we identified employees with the largest emotional contagion potential – people whose negative emotions are the most likely to create the largest negative overall impact by spreading to others. Table 1 displays the basic information on the top three most emotionally contagious persons. Data on such highly infectious people could be used to ascertain which qualities make a person more likely to spread emotions. (Some data have been obfuscated to protect the anonymity of respondents; each individual is at least 10-anonymous.)

Table 1: Top 3 most infectious persons (in descending order).

Gender	Age	Education	Field of work	Work hours	Work years
Female	41-50	University or more	Healthcare	21-40	0-20
Female	31-40	High school or less	Healthcare	21-40	21-40
Female	31-40	High school or less	Support staff	21-40	21-40

These highly contagious people are the prime targets for stress-reducing interventions; they are the people on whose targeted stress-reducing interventions are the most likely to have the largest positive overall impact on the entire group of people. In fact, we simulated such an intervention and the effect it has on the stress levels of the entire social network. Our hypothetical stress-reducing intervention decreased the stress levels of the employees by a randomly chosen value ranging between 0-40%. The model included the employees in order of their emotional contagion potential; those with the highest potential to impact the entire network were considered first. By summing the stress level values of all employees, we calculated the overall stress level score of the entire social network. This score was used to evaluate the effectiveness of providing hypothetical stress-reducing interventions to different numbers of employees.

Figure 2 shows the overall stress levels (of the entire social network) based on how many people received the hypothetical stress-reducing intervention. The x axis displays the number of targeted people by the hypothetical intervention, starting with the people that have the largest emotional contagion potential (on the left). The y axis represents overall stress levels in the entire group of employees (starting with the initial 100% value). As an example, the overall stress levels of all employees combined decreased to approximately 50% of the initial state when around 200 employees were targeted with the intervention.

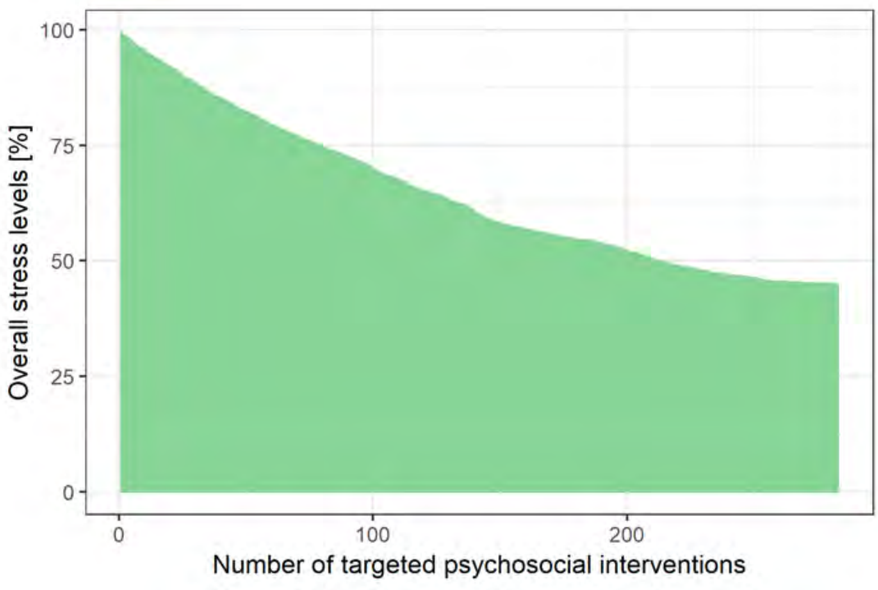

Figure 2: Overall stress levels with the growing number of psychosocial interventions.

4 CONCLUSIONS

Decreasing human stress is a challenging task. Due to the scope of the problem, stress-reducing approaches will often only scratch the surface; consequently, it is important that they are as efficient as possible. One way to increase their efficiency is to direct them at the persons with the highest potential for emotional contagion. With this, we can improve the well-being of a larger group of people despite targeting only select few. This can be achieved effectively with the application of certain network science methods.

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Appendix

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