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THEATRE, LOVE AND GRAPHS

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Abstract. In the paper, utilization of graphs in theatre-related issues is discussed. World-wide known plays are analysed: W. Shakespeare's "Measure for measure", M. Camoletti's "Boeing, Boeing" and Jarosław Murawski's "Humanka". The graphs represent relations among the heroes however they could be a part of scenography. Graph-based modelling allows for deeper understanding of attitudes and dependencies between dramatis personae, additionally unexpected visions of the plot are obtained.

Keywords: maggraph, clique, independent set, plot, deeper understanding

Mathematics Subject Classification: Primary 68R10, 05C90; Secondary 05C99

1 Introduction

The problems related to the topic "theatre and graph theory" are not recognized as classical ones. Sometimes, the search is even misleading because "operating theatre" is a place in a hospital. Moreover, theatre ventilating system or war theatre also could be found for these keywords. However, in our paper the word 'theatre' is considered as related to the art and it could be replaced by 'drama'. The phrase 'mathematics and theatre' is more promising, therefore several papers dedicated to graph application in theatrical matters can be listed, e.g.: [3-7]. The paper [3] gives a theoretical background for using graphs in modelling of drama related issues. It gives also a wide reference review and information how other theatre plays could be analysed via graph-based approach Works [4-6] of Italian scientist A.C. Sparavigna are extremely interested and fully fit to the discussed problems. The authors main interest is graph application in mechanics [11,14], however, special aspects were also propagated e.g. graph transformations utilization [10], design of technical artefacts (trusses) via evolutionary approach [12] as well as historical approach [9]. Moreover, writing plays' reviews is a hobby of the author [15]. The basic notions related to graph theory can be found in the classical book [8]. Graphs related to Shakespeare's plays can be seen in paper [3-6] and the webpage [2], which is dedicated to teaching of graph models of chosen plays at the University of Nebraska, Omaha, USA, whereas Greek tragedy in [17], respectively. Several graph-theatre assignment rules are given in this webpage, in [3] and in the present paper. Colour vertices and circle of different dimensions were used by Americans [2], whereas here different shapes of vertices as well as different line types are proposed.

The goal of the paper is to show how graph-based modelling is fruitful and adequate for theatre related issues. In general, the goal is also to propagate and promote graph theory learning and interest via showing unexpected but useful application. This direction of application was rather very narrow and relatively unknown. The new bust of interest is connected with the problem of a supported or an AI-supported story telling or scenarios creating for computer games [16] but also in general. So, it is recently intensively developed. Graphs turned into the useful algebraic structure to represent plot and maps of virtual world in the games. Also, these directions are under interest of the authors of the present work.

2 Short information on the considered theatre plays

In the present paper, three plays which are in the current repertoire of the theatre in Bielsko-Biała (Poland) – named "Teatr Polski" – are discussed. The first one is entitled "Humanka" – the word derived from 'human', whereas ending '-ka' (in Polish) is related to a female sex. To avoid placing quotation marks, the titles of the plays will be written in italics i.e. *Humanka*. The first drama author is a young Polish playwright Jarosław Murawski [1] who was graduated from the Warsaw University but also finished the course of scenario writing at The National Institute of Dramatic Art in Sydney in 2010. The play action takes place in next century when robots are fully identical to men. The hero is shy and a dweeb. So, he could not meet a faithful girl-friend – which is a dream of his mother. The model of 'humanka' bought by him is really intelligent, but mother is too clever to be fooled. Additionally, unexpectedly and baselessly the robot starts to be beloved in the hero. The love ends tragically. The second play which is discussed underneath is *Boeing, Boeing* by Marc Camoletti – famous French playwright. The play itself is known in tens of countries (over 50), being played for more than 50 years. At the moment it is played in Bielsko-Biala and in Trnava Theatre (in May 2017) under the title: *Tri letuški v Paríži* (Fig. 1).

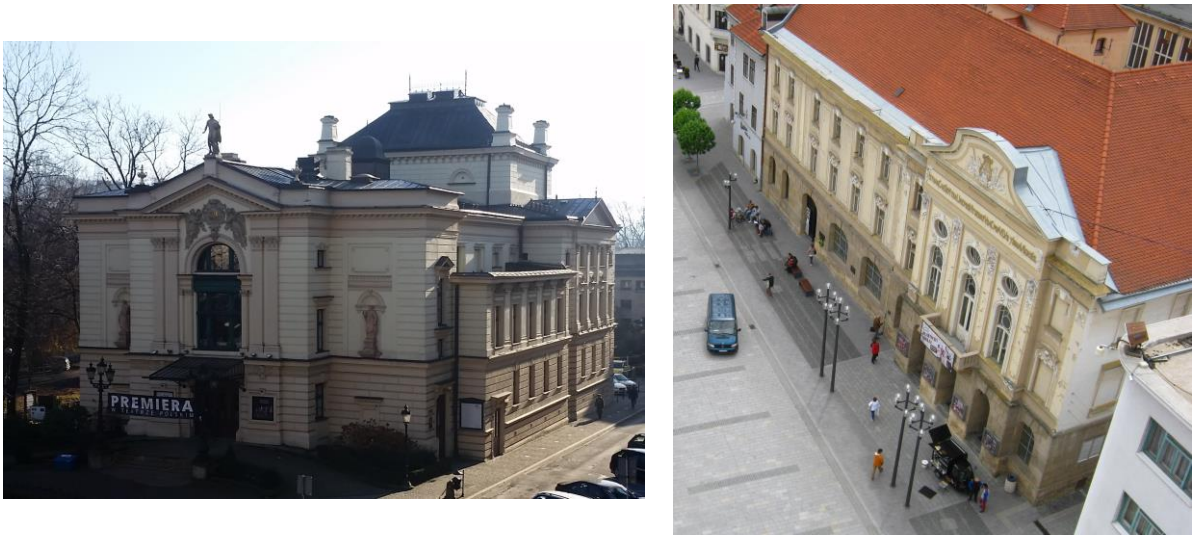


Fig. 1. Bildings of theatres in Bielsko-Biala and Trnava where drama *Boeing, Boeing* was played. (Author of photos: Stan Zawiślak)

The plot is simple: Bernard – who in Bielsko is called Maks – has three 'love affairs' with three stewardesses: Janet from USA, Jola from Poland and Johana from Germany. It is rather

‘affair’ then ‘love’. He has meetings with every one of them in the same time but not simultaneously, obviously. His school friend Paweł (Robert in the original version) comes. The matters start to be more complicated due to weather breakdown and consequently some delays of flights. Therefore three girls are coming to Maks simultaneously and due to Paweł help their meeting is initially avoided. They really need love, they are dreaming about gorgeous love. It seems, that they all are thinking seriously about requited love and marriage. It is well known American song where rhymes go: “Soldier, soldier! Will you marry me, with your musket, pipe and drum?” - but how Maks could marry three girls simultaneously? The solution to the problem is known by those who have seen this funny play.

The last considered masterpiece is the play *Measure for measure* by William Shakespeare. The plot is more complicated in this case. The drama was written in 1603. So, one of the heroes is prince. The procuress and prostitute occur, thereby so called (in Polish) ‘paid love” exists in the world. However, in English language, there are rather phrases “to pay for sex” or “for providing sex”. The action twists and turns. In general, the play heroes could be gathered in some groups of society: representatives of authorities, representatives of church as well as ordinary members of society, good and bad. The proposed graphs give an overview of this division or partitioning [13]. The drama ends in some marriages.

But what is love? According to the Bible “Love is patient, love is kind. It does not envy, it does not boast, it is not proud. It does not dishonour others, it is not self-seeking, it is not easily angered, it keeps no record of wrongs. Love does not delight in evil but rejoices with the truth. It always protects, always trusts, always hopes, always perseveres. Love never fails”. Even for those who do not respect the Bible, these features of love could be easily accepted. So, true love – how it could be reach? In the analysed plays – according to the mentioned authors it ends in marriage in some phase of its passing along.

3 Short review of terms related to graph theory and new type of graphs

A graph G – G(V,E) – is a pair of sets (V,E), where nonempty set V denotes graph vertices and set E contains the graph edges. If E is empty, then there are not any edges, so the graph consists of remote vertices. The graphs could be simple and directed. Directed graph i.e. digraph has such edges that each edge has the beginning and the end. In graphical graphs’ representations, these two graphs differs: edges of a simple graph are part of curves or parts of straight lines, whereas in digraphs edges are called arcs in which ends are marked by an arrow (more precisely arrowhead). A clique K_n or a full graph is such a graph which has all possible edges so if $|V(K_n)| = n$ than: $|E(K_n)| = m = 0.5 \cdot n \cdot (n-1)$.

The new notion is hereby introduced i.e. maggraph. The name is similar to ‘digraph’ which stands from ‘**di**rected graph’ – new graph could be named **mag**ic graph or big (**mag**nitude) graph due to the fact that notions biggraph, maxgraph or exograph are already known, therefore: MG(MV, ME), is a pair of magvertices and magedges, so MV is set of vertices which are particular graphs themselves and ME is set of edges connecting these vertices e.g. MV = {G_1, G_2, G_3}; ME = {(G_1, G_2), (G_1, G_3), (G_2, G_3)}. We can consider also extended maggraph i.e. maggraph plus the union of all graphs being its vertices, then magedges and edges could be presented graphically, simultaneously.

An independent set of vertices is a set of the graph vertices which are not mutually connected i.e. the vertices are disconnected. Graphs are inseparably connected with marriage i.e. there is commonly known Hall's theorem on marriages [8]. According to Wikipedia: "The graph theoretic formulation (of this theorem) deals with a bipartite graph. It gives a necessary and sufficient condition for finding a matching that covers at least one side of the graph." The graphical forms of the graphs could be different, usually vertices are shown as dots, circles or other pictograms. The describtion of vertices are placed inside these circles or in the neighbourhood of them.

Graph is equivalent to /0,1/-matrix A and to relation R - considered as a subset of Cartesian product of set V i.e. subset of the structure V × V, $R \subset V \times V$. As it was mentioned, there are n vertices belonging to the set V. Therefore, the matrix A has n × n elements as well as there are n × n pairs belonging to the Cartesian product. An existing pair corresponds to existing adequate graph edge and the adequate element of adjacency matrix is equal to 1 (confirming existence of the edge). The described equivalence is a base for representing relationships between play heroes if they are represented via graph vertices. The basic notions connected with graphs are also: cycle, tree – graph connected without cycles, path, partitioning etc. Their applications will be discussed in different dramas.

4 Graphs related to the discussed plays

The graphs related to the aforementioned dramas will be given and analysed in the following subchapters.

a) b)

Fig. 2. Newly delivered humanka Shi (a), dressed humanka (b).

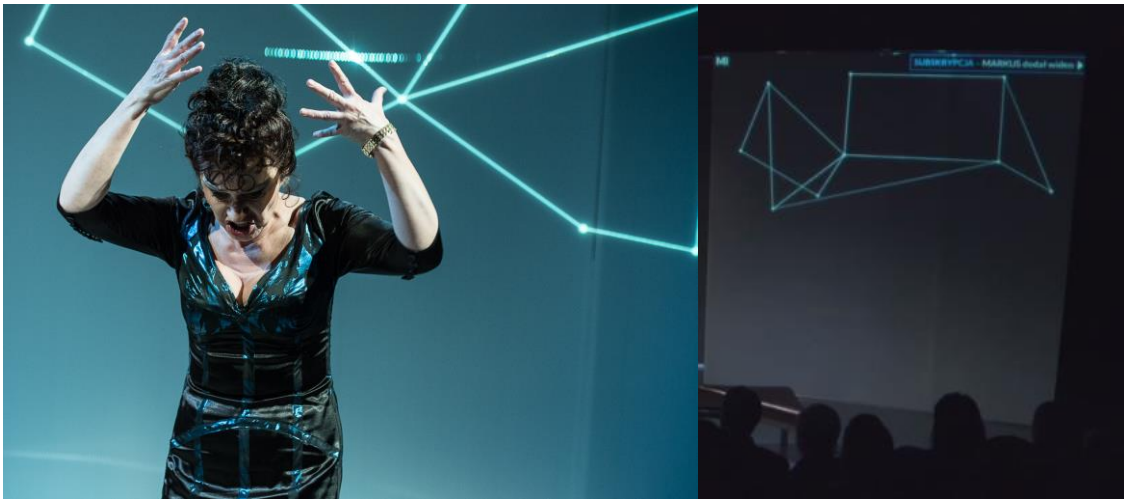
It is worth to underline that these graphs differs essentially which exposes variable ideas to build plots, relations among characters and general message bring via a particular drama. Graph vertices are assigned to the characters, the edges represent relation among heroes: being colleagues, being members of family or being members of the same social group of the society.

4.1 *Humanka* – the love-less society

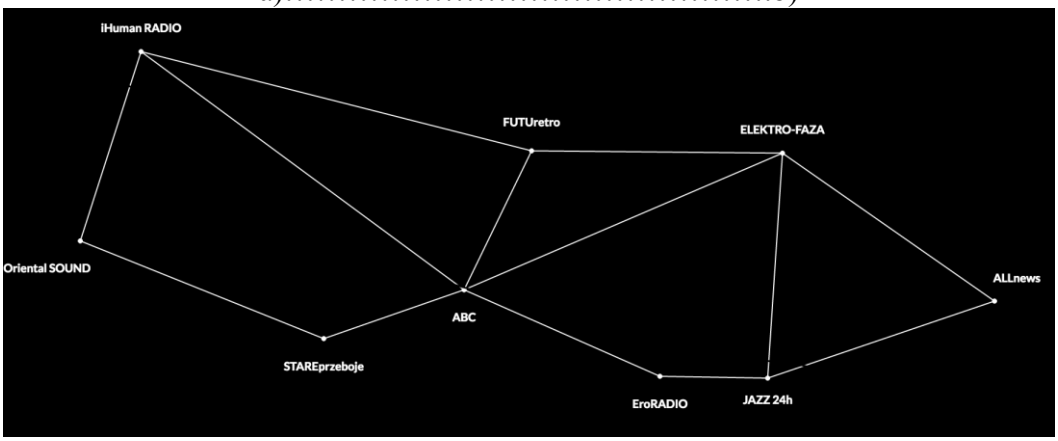
Like it was mentioned above, humanka is a human-like-robot. In Fig 2a, the newly unpacked humanka is shown, the switch button is placed on the neck. In Fig 2b, humanka is dressed. In Fig. 3a, Em's mother is presented, whereas a graph is visible in the background. The graphs are presented through the whole play on the rear side of the scene. It shows that future, novelty and technology according to scenographer is related to graphs which evolve in interesting manner. They are really attractive and important elements of dynamic scenography (delivered via an overhead beamer) which is rather rare in theatrical material-made artefacts.

4.1.1 Graphs as scenography

To our surprise, the graphs are a part of scenography in *Humanka*. During almost the whole play, on the rear wall of the small scene the graphs are shown via a special projector.



a)…….b)



c)

Fig. 3. Fuorios Em's mather – graph in the background (a), graph as constant element of the secenery of *Humanka* – first version (b), second version (c).

The graphs are expose as a stable picture or they evolves being a network of local media or being a screen of a new videophone – device similar to our smartphones. The difference is in

the dimensions of the screen. The graphs are presented in Fig. 3. It was really an inspiration to go further and utilize graphs for plays' analyses. The graph used as a videophone allows the hero to contact with some characters e.g. friend and father. Father (and others) even do not play as live actors, only movie - shown by means the videophone - informs the audience about the conversations of son and daddy.

4.1.2 Graphs representing the characters who are in some mutual connections

Two graphs representing the relations among drama heroes are presented in Fig. 4. In Fig. 4a, an initial situation is presented via a graph being a tree, especially a star. Father and mother are not connected because they are divorced. Em is in the centre of stage as well as in the middle of the action. The star like graph represents also a hub-like computer network where branches connect the hub with the so called slave computers. Humanka is really like a slave for him. However, he could be treated as an anti-star. His ex-girlfriend is prowling around but there is not any future for conciliation. She disappears eventually. Humanka Shi declares love to Em. He is furious, rejects love and resets the robot (clears her memory and feeling if they are stored separately)! Performance of the reset procedure is really tragically. Moreover it is shown in a touching way by the actress, and it is also tragic itself. Then, Em is selling the robot with cleared circuits and memory to his friend. It is an absurd and merciless act simultaneously. The audience realize that mother has a much much younger boyfriend. Such a pair is really popular in so called colour tabloids nowadays. Em's father has bought the same model of humanka as his son! Despite the fact that mother has a youth boyfriend, this information (passed to her by Em) makes her mad.

After this action the graph converts in a new one (Fig. 4b) where information about father's purchase and mother's boyfriend are taken into account. The final graph is also a tree. Em remains in the centre but he is even more lonely then previously. Father related vertex is shown as a rectangle because the father is known by theatre audience only from the video registration shown as a part of videophone connections. Some other actors appear only in the movies shown on the screen, so they are not enclosed in the graphs.

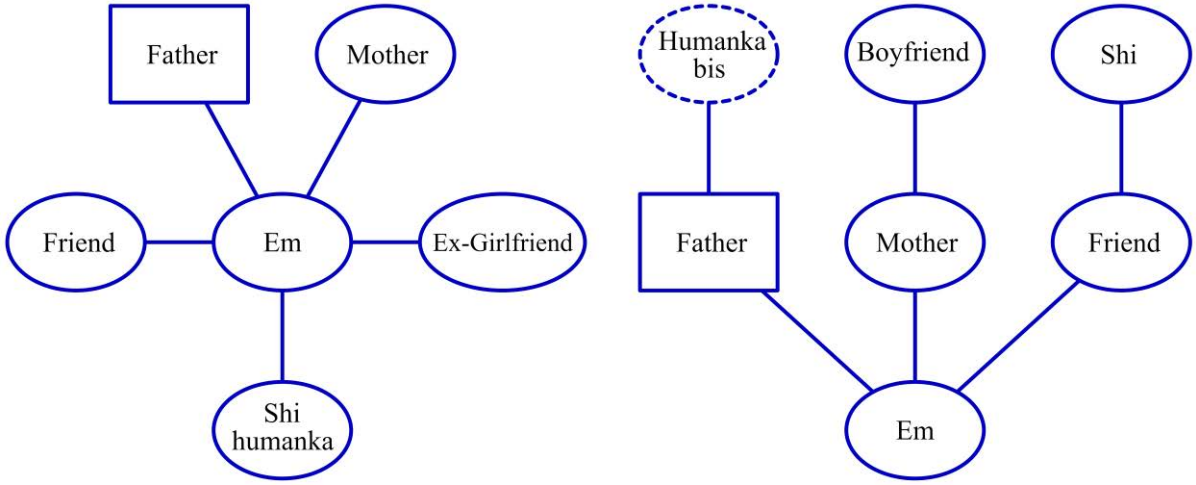


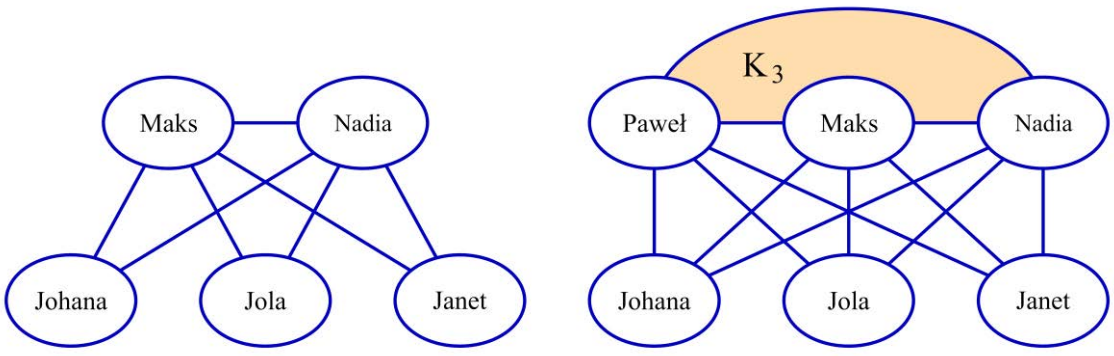
Fig. 4. Graphs of relations between heroes of *Humanka* - initial (a), final (b).

They are not taken into account in the considered graphs besides the father of Em which is also a subject of discussion the hero with mother. The vertex 'Humanka bis' is encircled via a dashed line to show that the character is only discussed by the remaining heroes. In both cases the graphs are symmetrical. Is only an incidence or it was deliberately planned by the author? The play is genially prepared by a theatre team. Actress Oriana Soyka was rewarded by the diploma of the Mayor of the town Bielsko-Biala at the beginning of 2017. Maybe, the spectators are forced to rethink their relationships with friends, family, spouse and beloved person. Such a world is suggested to be in a far far future, but it is even present nowadays?

4.2 *Boeing, Boeing* – desire for love

There are five heroes of the drama *Boeing, Boeing* at the beginning of the plot. The adequate graph (Fig. 5a) is given. We can distinguish two subgraphs related to the following two distinct vertex sets: V_1 = {Maks, Nadia} and V_2 = {Johana, Jola, Janet}. The subgraphs induced on these sets are clique K_2 and the independent set V_2. When the Maks' friend comes, the graph converts into similar one (Fig. 5b.).

There is a possibility to distinguish two subgraphs: K_3 and a subgraph containing three separate vertices, the same idea as previously. A possible meeting of three stewardesses could be a disaster for Maks but also for women themselves – realizing that they were deceived. In general, the stewardesses are the most intelligent women working in stressful situations, knowing foreign languages and having a good contact with plane passengers – so in case of Maks' fiancés they are obviously full of suspicions – the comedy consists in finding excuses for them. Sometimes such an excuse triggers new suspicion. Live in permanent lie is not too comfortable. The graph K_3 in known as a clique. The word 'clique' has a pejorative connotations in Polish language. In fact, our clique have to make tricks all the time. The idea of independent set is here also highlighted – the stewardesses do not know each other almost for the whole period of the drama.



a) b)

Fig. 5. Graphs representing acquaintanceship realation among heroes of *Boeing, Boeing* - initial (a), just after comming of Maks's friend (b).

Meetings of Paweł and Johana cause that their feelings evolve from interest, respect, finally into a deep love – just immediately, due to the idea of the drama author. It is even more really funny in Poland, because there are stereotypes that marriage of Pole and German is impossible. Nevertheless, the authors know some happy marriages of this type. Finally, the

strongest feelings between Maks and Jola are announced. It seems for a moment that Janet remains without a pair. However, an unopened letter which had been circulating around, finally has been delivered to Janet. Its opening and reading brings an unexpected solution. Janet's American boyfriend declares love and proposes marriage. Janet is delighted and leaves Maks' home immediately, dreaming about the return journey to USA. Only Nadia remains alone. Happy end (Fig. 6a) is also for her, after a sound rise of her salary by Maks, she decided to remain as a home-keeper. In Fig, 6b, the maggraph for initial situation is presented. It represent ugly clique vs. innocent girls. Maggraph has two magvertices: MV = (G_1, G_2), G_1 is a smallest clique, G_2 is a disconnected graph. There is known a phrase "Nokia – connecting people", but here lack of connections means also that the girls are unknown one for another.

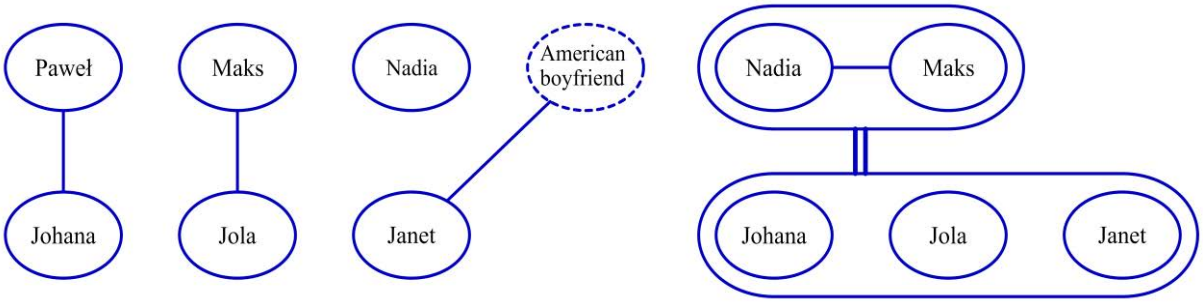


Fig. 6. Happy end of *Boeing, Boeing* (a), maggraph representing the play (b).

The comedy is played for over 50 years The story is really unbelievable. Nevertheless, it gives the spectators two hours of laugh and then time for rethinking. In case of graph representation – interesting is antithesis of clique and disconnected graph or independent set of vertices in original graph – depending on interpretation.

4.3 *Measure for Measure* – love and society

William Shakespeare was really a genius playwright. He observed the contemporary society with passion, understanding and admiration. In his drama entitled *Measure for measure*, published in 1623, he wrote about relationships between authorities and society. Introduction of a new law, faces a resistance almost in every case in every country.

Magedge	**Despription of mutual attidudes between particular parts of the society according to Shakespeare**
POWER → CHURCH	Power and church are separated and there is a lack of any tension between them. The Duke turns himself to a frair to observe an acction from coverture.
POWER → PEOPLE	Power would like to introduce new strict low, the Duke is afraid of the reaction of the people so gives temporary the power to Angelo to save his image as a good ruler.
CHURCH → POWER	Like it was previously mentioned, total separation. Rules of

	monastery are strict and they are related to internal matters of the monastery. Church is not the source or inspiration of new law however it is in agreement with the articles of faith. Church has to help the poor.
CHURCH → PEOPLE	Church does not force people. Monk being priest organizes the marriage ceremony. Isabella begs for merci for his brother and she would not resign of the church rules even when her brother will be beheaded.
PEOPLE → POWER	Part of society – criminals/offenders – are aginst new law. Their opinions is that new law is pointless because people will not obey it. The men are evil and they would like to have contacts with prostitutes. It was written around 400 years ago, but even nowadays the same opinions can be red.
PEOPLE → CHURCH	People respect the church.

Tab 1. Remarks on the meaning of magedges of maggraph shown in Fig. 7.

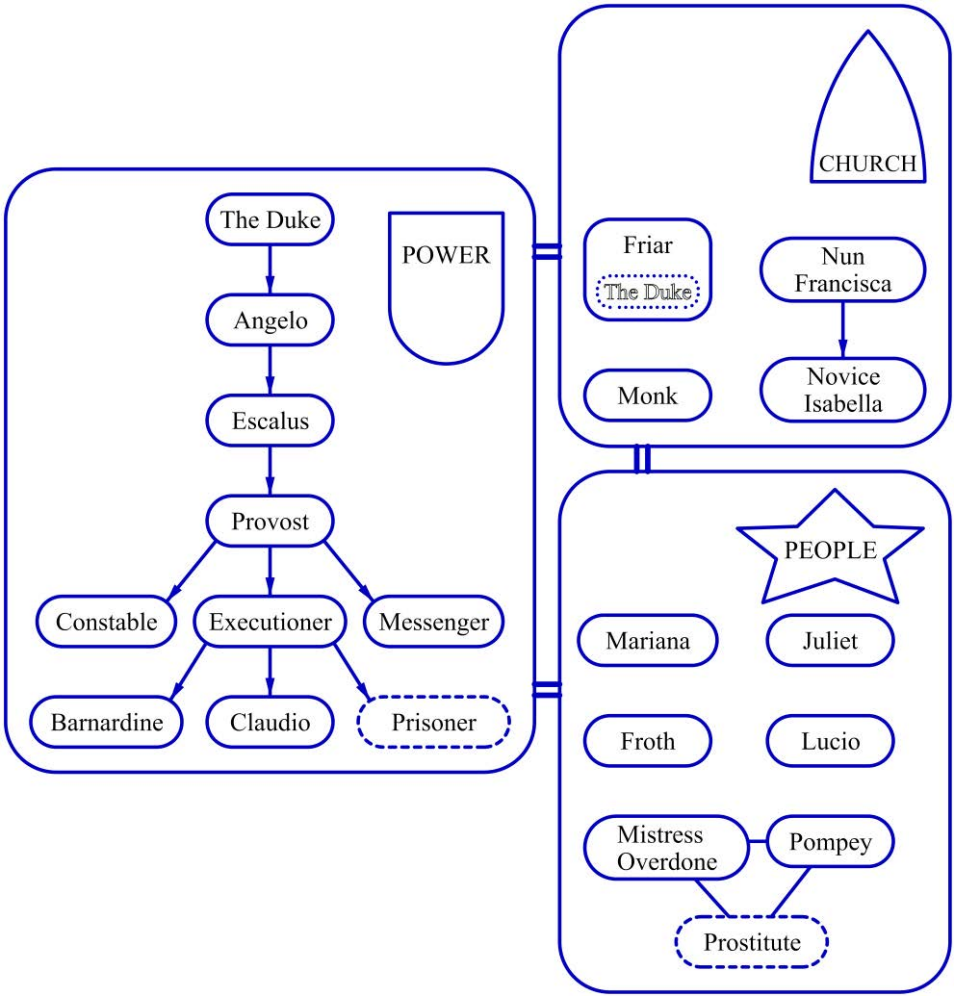


Fig. 7. First maggraph of *Measure for measure*.

In this case, new low is directed against promiscuity and for a **pure love** between men and women. The action is situated in Vienna, thence not in Britain where Anglicanism were introduced by the King Henry VIII. Those citizens who were surprised by new regulations have to be punished in as serious way as possible – even cruel one – to show determination of authorities in keeping the regulation. Claudio was sentenced for a dead punishment, at the beginning. The merciless prince would like to perform punishment. However, he hidden himself in other personality i.e. monk and observes the situation from the perspective of an ordinary citizen however belonging to a catholic church. Claudio's sister Isabell asks for forgiveness for her brother. She is a novice in convent, nevertheless she wears a nun uniform (habit). Usually, to be a nun, it is needed to swear an oath. So, even being a novice she looks like a regular nun.

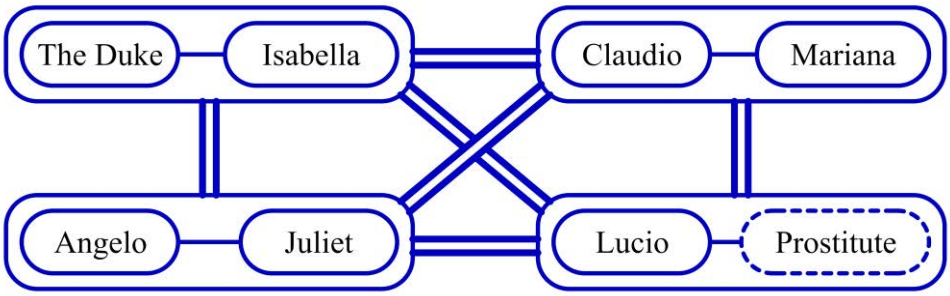


Fig. 8. Second maggraph of *Measure for measure* – happy end.

The maggraph of the situation presented in *Measure for measure* is shown in Fig. 7. The magvertices set = {power, church, people}. The set of magedges is described in Table 1. The MV_1 = 'power' is a digraph because a power i.e. the authorities have a clear structure of subordination, from top to bottom. In Bielsko-Biała realization, there are a few actors less than in an original text of Shakespeare. In this case, the graph has the vertical axis of symmetry. Like previously the heroes who are only discussed but not present in the scene are marked via dashed lines e.g. prostitute and prisoner (however his head was delivered to authorities to confirm the performance of the dead punishment). The magvertex MV_2 'church' is a disconnected graph: nuns and monks are separated, however the connectivity components 'nuns' is a directed subgraph due to hierarchy: prioress and novice. The magvertex MV_3 'people' is also a disconnected graph, society is divided into classes or honest and dishonest individuals. The clique represents those who break the law. The maggraph in Fig. 8 represents the marriages. It has two symmetry axes which symbolizes stability and harmony! The Duke forces the novice to leave the convent but it is also a gesture to reward her determination in rescue of her brother. Marriage of Lucio with pregnant prostitute is commanded or forced by the Duke. It is a sign of noble respect for women in general.

5 Conclusions

In the paper, three dramas were discussed. A real inspiration and a trigger to write a present paper was the scenography to *Humanka* where graphs are immanent part of decor, expressing new era, technological possibilities and world-wide web of connections. Additionally, several graphs were assigned to the theatre related matters for the discussed artistic works – e.g. representing the relationships among the heroes. All the considered plays are related to idea of

love. Love is an essential idea of a human life therefore the playwrights feel correctly that this could attract the audience and makes that theatres are full of viewers. The graphs allow the spectators for deeper understanding of the plays' plots as well as give new insight in the plays via detection of variable types of graphs. What is the most important, a new type of graph was introduced giving a graphical view emphasising the special aspects and differences between plays and their heroes. Graphs (obviously in graphical manner but not only) show in one glimpse differences among dramas' plots e.g.: *Humanka's* tree shows main hero (in fact weak creature), the conversion of a tree onto a tree shows – in our opinion – some tragic aspect of selling a robot and remaining in the same situation. Contradistinction of a clique and an independent set is a clue of tension in *Boeing, Boeing*. Overcoming of this tension results in partitioning of graph i.e. splitting the group of heroes into marriages. The plot of *Measure for measure* is in Shakespeare style – full of trestles – but graph gives a clear vision of groups of heroes: power, church and people. Moreover internal division of these general entities into subgroups also helps to put in order the individual characters: nuns and monks, ordinary people and underclass (dregs). It is really amazing how fruitfully graphs fit to theatrical plot and characters' relationships. And even nomenclature like e.g. clique, independent set or star catch precisely the essences of particular problems. It seems that playwrights have to use graphs to think, rethink or overthink the plots and the figures in their arts.

Acknowledgement

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Appendix: Names of Actresses and Actors

It is difficult to list all the creators of art like e.g. at the end of every movie where the list of all people involved in production are usually listed. In our case, we give the names of Actresses and Actors (in alphabetical order) to pay them the due respect:
(a) *Humanka:* Michał Czaderna, Piotr Gajos, Barbara Guzińska, Sławomir Miska, Adam Myrczek, Daria Polasik-Bułka, Anisa Raik, Grzegorz Sikora, Oriana Soyka; Zofia Schwinke, Mateusz Wojtasiński;
(b) *Boeing, Boeing*: Anita Jancia, Agnieszka Rose, Rafał Sawicki, Oriana Soyka, Wiktoria Węgrzyn, Mateusz Wojtasiński;
(c) *Measure for measure*: Michał Czaderna, Kazimierz Czapla, Piotr Gajos, Łukasz Kaczmarek, Jagoda Krzywicka, Maciej Kulig, Tomasz Lorek, Grzegorz Margas, Sławomir Miska, Adam Myrczek, Daria Polasik-Bułka, Bogdan Słomiński, Grzegorz Sikora, Oriana Soika, Maria Suprun, Wiktoria Węgrzyn, Mateusz Wojtasiński.

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