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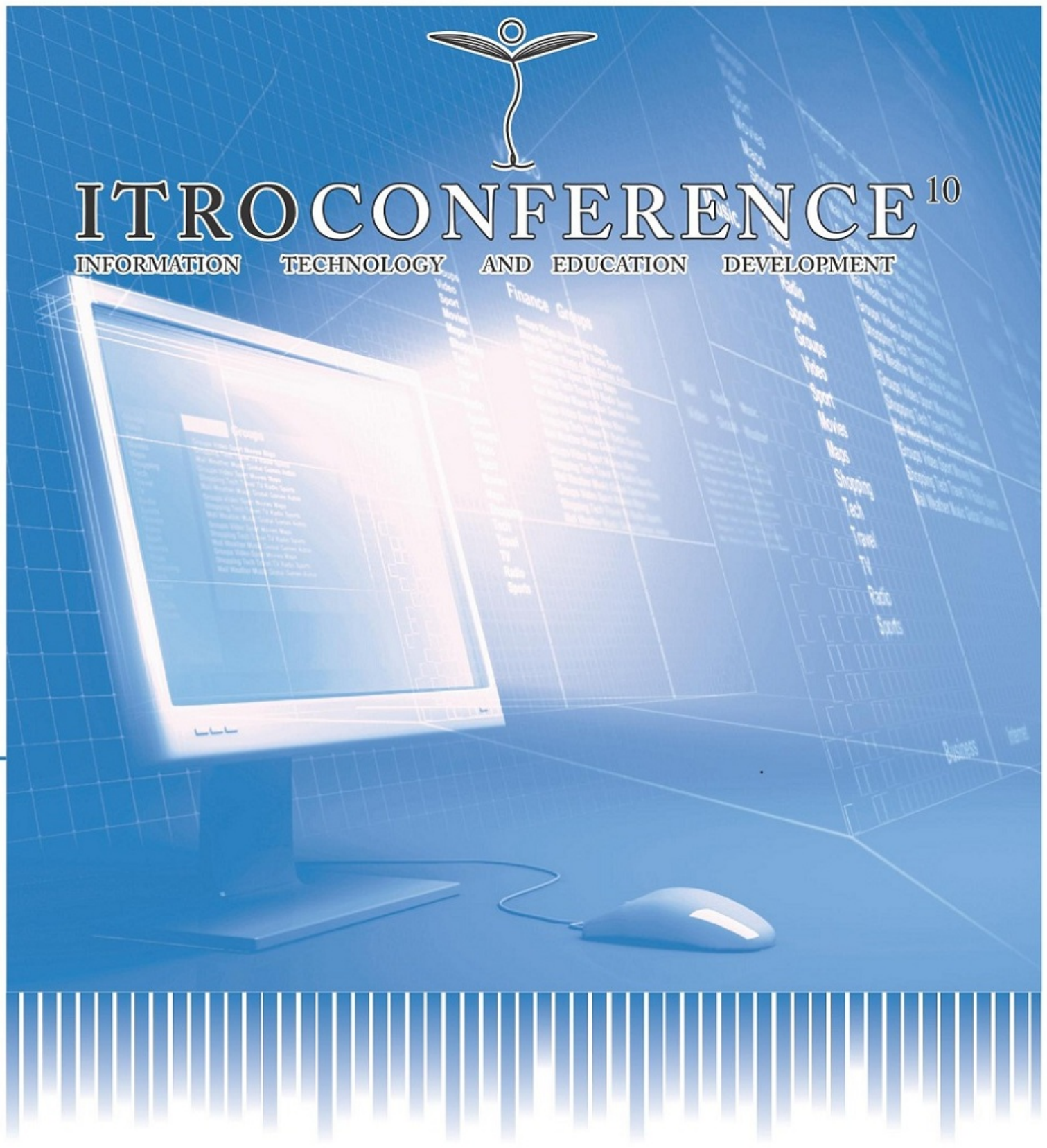

ITROCONFERENCE 10
INFORMATION TECHNOLOGY AND EDUCATION DEVELOPMENT

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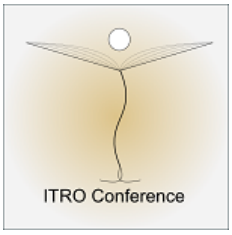

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With this publication, the CD with all papers from the International Conference on Information Technology and Development of Education, ITRO 2019 is also published.

INTRODUCTION

International Conference on Information Technology and Education Development (ITRO 2019), was held the jubilee tenth time. Since the very beginning, the conference has been connecting science, profession and experiences in education. Information technologies influence educational processes and student achievements. Contemporary topics relate to Interactive EBooks and electronic Teachers logbooks. Thematic fields of the conference are alined with general, but olso with national trends in education:

- Theoretic and methodology questions of contemporary pedagogy
- Digital didactics of media
- Modern communication in teaching
- Curriculum of contemporary teaching
- E-learning
- Education management
- Methodic questions of natural and technical sciences subject teaching
- Information and communication technologies
- Dual education.

The conference work was contributed by plenary lectures covering various aspects of ICT in education development:

- *Digital transformation of educational system in Higher Education*, Branko Perišić, Faculty of Technical Sciences, University of Novi Sad;
- *Security issues of e-learning system*, Igor Franc, E-security, Belgrade;
- *From E to ES teacher logbooks*, Žarko Mušicki, primary school "Žarko Zrenjanin", Novi Sad;
- *Canvy, The Thrue Story of Mobile App*, Marius Marcu, Politechnica University of Timisoara, Romania.

The Proceedings containes 59 articles based on research and scientific work in the field of information technologies in education.

The conference was financially supported by the Provincial Secretariat for Higher Education and Scientific Research, Novi Sad. The Technical Faculty "Mihajlo Pupin" has provided the necessary technical support.

The ITRO Organizing Committee would like to thank to the authors of articles, reviewers and participants in the Conference who have contributed to its tradition and successful realization.

Regards until the next ITRO Conference,

Chairman of the Organizing Committee

Jelena Stojanov

We are very grateful to:

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CONTENTS

SCIENTIFIC PAPERS

SCIENTIFIC PAPERS

Bellman-Ford and Floyd Warshall Algorithms for Easier Learning

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Abstract - In this paper, Bellman-Ford and Floyd Warshall Algorithms will be considered. Floyd-Warshall is used when we want to find the shortest path between all the pairs of nodes in graph. The Bellman-Ford algorithm is similar to Dijkstra algorithm, but it is used when the graph may also contain links with negative weights. The algorithms are implemented in Java and visualized for easier learning.

I. INTRODUCTION

Graphs are abstractly mathematical objects that are often used in everyday life:

- a geographical map with many cities connected with path;
- set of people somehow connected;
- Structural formula of a molecule or compound;
- Scheme diagram of an electrical circuit.

Graph describes the relationship between lines and points. A graph consists of some points and lines between them. The points are called nodes or nodes and the lines are called edges or links.

Formally, a graph is a pair (V, E), where V is a finite set of nodes and E a finite set of links.

The graphs are used for describe models and data structures. The structure of a web presentation can be graphically represented by the use of the graph. The nodes of that graph are individual pages, and the edges of the graph are the links that one page can pass to another.

There are several types of graphs:

- A simple graph in which there are no loops and parallel links.
- A regular -graph in which all nodes have the same degree (the number of links incident to the vertex).
- A complete graph Kn is a graph with n nodes in which each two nodes are adjacent.
- Bipartite graph is a simple graph G whose set of nodes can be separated into two non-empty disjunction sets V1 and V2 so that the nodes of V1 can be linked with V2 nodes, but no V1 theme is linked to a V1 itself and no V2 theme is linked to a V2 theme itself.

II. BELLMAN-FORD ALGORITHMS

Bellman-Ford algorithm is an algorithm that find the shortest paths from a single source in a directed weight graph (Figure 1). The name of this algorithm comes from Richard Bell and Leicester Ford, who first published it in scientific papers in 1958 and 1956, but Alfonso Schimbel first proposed this algorithm as a solution since 1955. The advantage of the Belman-Ford algorithm vs. classical algorithms for searching the shortest paths as the Dijkstra algorithm is that it can work with graphs that have links with negative weights. This algorithm is slower that Dijkstra and is more complex. Rarely, we have graphs where the weights of links are negative numbers [1], [2]

```
BELLMAN-FORD(G,w,s)
1.  INITIALIZE-SINGLE-SOURCE(G,s)
2.  for i = 1 to |G.V|-1
3.     for each edge (u,v) ∈ G.E
4.        RELAX(u,v,w)
5.  for each edge (u,v) ∈ G.E
6.     if v.d > u.d + w(u,v)
7.        return FALSE
8.  return TRUE

INITIALIZE-SINGLE-SOURCE(G,s)
1.  for each vertex v ∈ G.V
2.     v.d = ∞
3.     v.pi = NIL
4.  s.d = 0

RELAX(u,v,w)
1.  if v.d > u.d + w(u,v)
2.     v.d = u.d + w(u,v)
3.     v.pi = u
```

Figure 1 The pseudo code for the algorithm

In Figure 2, is given graph with 5 nodes and links between them.

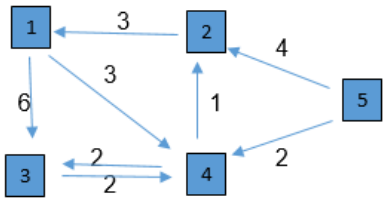

Figure 2 Directed graph

For node 5:

Iteration 0: Node 5 is source (the distance is inicialized to zero), distance to the other nodes are inicialized to ∞. (Figure 3)

Итерација 0:

	5	4	3	2	1
d	0	∞	∞	∞	∞
p	/	/	/	/	/

Figure 3 Iteration 0

Iteration 1: We relax the links (u5,u2) and (u5,u4) and update the distances to 2 and 4. The iterations 1 is given in Figure 4.

Итерација 1:

	5	4	3	2	1
d	0	2	∞	4	∞
P	/	5	/	5	/

Figure 4 Iteration 1

The iterations 2 and 3 are given in Figure 5 and Figure 6.

Итерација 2:

	5	4	3	2	1
d	0	2	4	3	7
p	/	5	4	4	2

Figure 5 Iteration 2

Итерација 3:

	5	4	3	2	1
d	0	2	4	3	6
p	/	5	4	4	2

Figure 6 Iteration 3

```
<terminated> BellmanFord [Java Application] C:\Program Files\Java\jre1.8.0_191\bin\jav
Vnesete go pocetniot jazel:
5
Vnesete go krajniot jazel:
5
Najkratkoto rastojanieto od temeto  5 do temeto 5 e 0
Vnesete 1 dokolku sakate da ispitate najkratko rastojanie
5
Vnesete go pocetniot jazel:
5
Vnesete go krajniot jazel:
4
Najkratkoto rastojanieto od temeto  5 do temeto 4 e 2
Vnesete 1 dokolku sakate da ispitate najkratko rastojanie
5
Vnesete go pocetniot jazel:
5
Vnesete go krajniot jazel:
3
Najkratkoto rastojanieto od temeto  5 do temeto 3 e 4
Vnesete 1 dokolku sakate da ispitate najkratko rastojanie
5
Vnesete go pocetniot jazel:
5
Vnesete go krajniot jazel:
2
```

Figure 7 Bellman-Ford algorithm (Java implementation)

III. FLOYD WARSHALL ALGORITHMS

The Floyd Warshall algorithm is used when we want to find the shortest paths between all pairs of nodes in a graph. This algorithm is an example of dynamic programming [3], [4].

The following graph with 6 nodes is given.

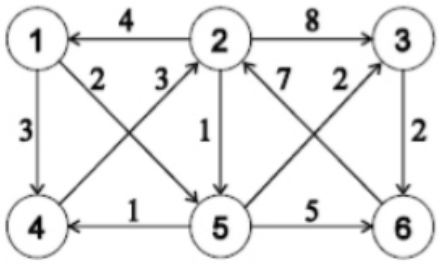

Figure 8 Floyd Warshall algorithm

The procedure for finding the shortest path using this algorithm is that with several iterations it forms few matrices. The first matrix is filled in if there is a link between the i - th and the j - th node appropriately inserts the weight value; if such a link does not exist, we put a sign ∞. In cases when we need to insert a value of a link whose end and beginning is the same node, we put 0 because we can notice that there are no loops.

Each subsequent matrix is created according to the rule min (d_{ij}, $d_{ik} + d_{kj}$) so that k is the constant that initially increases with each subsequent matrix creation. The size d_{ij} is defined as the minimum weight of the path from the node j to the node i with medium nodes of the set {1,2 ... k}.

On this way, we obtain the following results:

$$C^0 = C = \begin{bmatrix} 0 & \infty & \infty & 3 & 2 & \infty \\ 4 & 0 & 8 & \infty & 1 & \infty \\ \infty & \infty & 0 & \infty & \infty & 2 \\ \infty & 3 & \infty & 0 & \infty & \infty \\ \infty & \infty & 2 & 1 & 0 & 5 \\ \infty & 7 & \infty & \infty & \infty & 0 \end{bmatrix}$$

Figure 9 Matrix $C^0 = C^1$

$$C^2 = \begin{bmatrix} 0 & \infty & \infty & 3 & 2 & \infty \\ 4 & 0 & 8 & 7 & 1 & \infty \\ \infty & \infty & 0 & \infty & \infty & 2 \\ 7 & 3 & 11 & 0 & 4 & \infty \\ \infty & \infty & 2 & 1 & 0 & 5 \\ 11 & 7 & 15 & 14 & 8 & 0 \end{bmatrix}$$

Figure 10 Matrix C^2

$$C^3 = \begin{bmatrix} 0 & \infty & \infty & 3 & 2 & \infty \\ 4 & 0 & 8 & 7 & 1 & 10 \\ \infty & \infty & 0 & \infty & \infty & 2 \\ 7 & 3 & 11 & 0 & 4 & 13 \\ \infty & \infty & 2 & 1 & 0 & 4 \\ 11 & 7 & 15 & 14 & 8 & 0 \end{bmatrix}$$

Figure 11 Matrix C^3

$$C^4 = \begin{bmatrix} 0 & 6 & 14 & 3 & 2 & 16 \\ 4 & 0 & 8 & 7 & 1 & 10 \\ \infty & \infty & 0 & \infty & \infty & 2 \\ 7 & 3 & 11 & 0 & 4 & 13 \\ 8 & 4 & 2 & 1 & 0 & 4 \\ 11 & 7 & 15 & 14 & 8 & 0 \end{bmatrix}$$

Figure 12 Matrix C^4

$$C^5 = \begin{bmatrix} 0 & 6 & 4 & 3 & 2 & 6 \\ 4 & 0 & 3 & 2 & 1 & 5 \\ \infty & \infty & 0 & \infty & \infty & 2 \\ 7 & 3 & 6 & 0 & 4 & 8 \\ 8 & 4 & 2 & 1 & 0 & 4 \\ 11 & 7 & 10 & 9 & 8 & 0 \end{bmatrix}$$

Figure 13 Matrix C^5

$$C^6 = \begin{bmatrix} 0 & 6 & 4 & 3 & 2 & 6 \\ 4 & 0 & 3 & 2 & 1 & 5 \\ 13 & 9 & 0 & 11 & 10 & 2 \\ 7 & 3 & 6 & 0 & 4 & 8 \\ 8 & 4 & 2 & 1 & 0 & 4 \\ 11 & 7 & 10 & 9 & 8 & 0 \end{bmatrix}$$

Figure 14 Matrix C^6

By executing the Floyd Warshall algorithm, we get the matrix C^6 that gives the shortest paths between all the pairs of nodes in the graph. For that purpose, it is necessary first to insert the graph through the matrix of neighborhood.

```
0
Najkratkite patista na site parovi od jazli se dadeni so:
        1       2       3       4       5       6
1       0       6       4       3       2       6
2       4       0       3       2       1       5
3       13      9       0       11      10      2
4       7       3       6       0       4       8
5       8       4       2       1       0       4
6       11      7       10      9       8       0
```

Figure 15 Floyd Warshall algorithm (Java implementation)

IV. CONCLUSION

In the paper Bellman-Ford and Floyd Warshall algorithms were considered and implemented in Java programming language. This was made because we think that with graph visualization students can learn algorithms more easily and with great desire. Despite programming languages, there are so many other software for algorithm visualization [5], [6], [7]. So our next goal is to choose a good software and to use it for algorithms visualization.

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