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# The concept of an intelligent system of an outfit completion

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Abstract. The article considers the main criteria for the selection and formation of the wardrobe, which is one of the areas of application of methods and means for image classification. Typical software solutions for the task are analyzed, and the Analytic Hierarchy Process was used to analyze such applications. To improve the wardrobe selection process, the concept of an intelligent information system based on the use of convolutional neural networks was proposed.

*Keywords*: neural network, wardrobe, pattern recognition, image classification, convolutional neural networks, Analytic Hierarchy Process

## INTRODUCTION

An important component of the material world is clothing both as a means of aesthetic education of the individual, and a thing of first necessity. At the same time, clothing is an essential thing, because a person uses different types of clothing in different life situations [1]. However, people nowadays might not always have the time to quickly and according to all the fashion trends choose an outfit for every day or other event, without taking into account updating the wardrobe and finding images. Therefore, the classification of objects according to certain criteria (color, type, occasion, etc.) so that the search for a particular group or *close* style does not require much time and effort, is an actual practical task.

## SOFTWARE APPLICATIONS IN DIGITAL FASHION

Trading over the Internet has become a worldwide casual practice. The online selling approach gives a chance to small companies with unique products, as well as vulnerable social groups to do their business openly and freely [2]. To improve the activity and management of fashion companies' strategy in online business, authors in [3] developed a model, which takes into account, social networking, participation, engagement, feedback, etc.

A properly organized wardrobe significantly improves the quality of life, allowing you to instantly find the right clothes and keep them in good condition. At present, there are many software products on the market that allow you to not only shape your outfit but also look for inspiration to form images or suggest how to dress for the weather. Several of them were analyzed:

*Smart Closet*, a convenient application for choosing clothes online, allows for creating a *smart* image for both women and men (Fig. 1). The interface is English. It works on the rules of choosing things from many permitted brands and storing them in a *virtual* wardrobe. Or downloading photos from a smartphone (photo processing is allowed, with removing the background, changing the color, etc.) and self-distribution to a certain category of things with the addition of extra information (price, brand, season).

Also, in this application one can keep a calendar of images and create an online wish list.

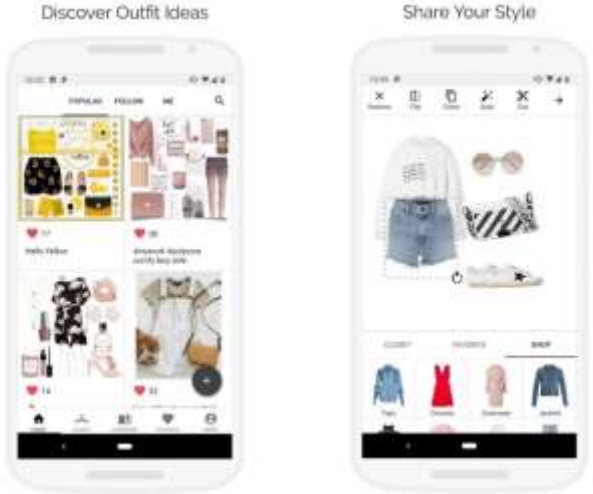


Fig.1. *Smart Closet* mobile application interface

*Your Closet - Smart Fashion* is a digital English-language assistant that helps to organize a wardrobe, create stylish outfits, plan with a calendar, scanning, search, and select by color (Fig.2).

There is also an option Online store for a quick search for things that you like in various online stores. The system also makes recommendations by analyzing your wardrobe and the things user likes.

With Google Drive backup and sync, the application takes care of the data storage.


Fig.2. The interface of the mobile application *Your Closet - Smart Fashion*

The *Lookbook - create your image*! is quite a popular application, which is similar in functionality to Polyvore (Fig.3). To create images, you can use images from the application or upload photos of your things. It is possible to sort things by type, brand, color palette, models, and other parameters. The virtual assistant monitors current fashion trends, recommends articles on fashion, and notifies about changing trends.


Fig.3. Mobile application *Lookbook - create your image*! interface

What is of great importance, such kind of application can be used to support an everyday life of a person with health impairments. Having a clear plan of what to wear can improve the everyday life of a person, with, for example, autism. Such persons feel more comfortable in well-structured world [4], and communication using information technologies can be more comfortable. Among available, it can be difficult to choose the most appropriate because of the great number of criteria, by which the ITs can be evaluated. That is why choosing the best information technology can be organized with such decision making-technique, ad analytic hierarchy process (AHP) [5]. When dealing with choosing an application for a person with special needs, to evaluate available ITs different experts can be involved, except the person with special needs, it can be psychologist, close friends, and, what is of great importance, an IT-specialist, who could evaluate the application on content accessibility [6].

## ANALYTIC HIERARCHY PROCESS

The AHP is traditionally used in decision-making, and applied with variations in a very wide range of scientific and practical directions, i.e. medicine, economics, ecology [7]-[9], etc. Applying AHP, the following steps should be performed.

1. Determination the goal
2. Establish decision hierarchy
3. Find relative priority for each alternative on the basis of the pair-wise comparison matrix. Determine the consistency of judgments.
4. Make decision

The final result is the ranged alternatives, and the alternative with the highest range is the one the most highly evaluated by experts. The step-by-step performed AHP will illustrate how the best fashion application, among available, can be chosen.

### 1. Determination the goal

The main goal is to choose an application among available, that would support the everyday what-to-wear activity for a person, who feels more comfortable when his/her day is well-planned.

### 2. Establish decision hierarchy

To do so, it should be decided what are the crucial criteria according to the main goal. In case of the goal from above, such criteria could be:

- the ease of navigation in an application,
- the person-adjustment level of an application,
- the compliance of application`s demands with basic technical characteristics of person`s gadget,
- the price of an application,
- the level of errors,
- backup support,
- compliance with other products and services,
- a system resources consumption,
- the compliance of the application with content accessibility demands (ISO),
- the availability of characteristics that disturb from the main functions (advertisements), etc.

The alternative applications can be compared according to some criteria, which correlate with the main goal. For example, let us choose some criteria from the above, the compliance with other products and services,

the compliance of the application with content accessibility demands, the ease of navigation in an application, and the person-adjustment level of an application. Then let $C = \{C_i \mid i = 1,...,4\}$ be a set of the mentioned criteria, and $A = \{A_j \mid j = 1,...,3\}$ is a set of three alternative applications among which one should choose (Table 1, Table 2). The decision hierarchy is in fig. 4.

### 3. Find relative priority for each alternative on the basis of the pair-wise comparison matrix. Determine the consistency of judgments

On the basis of experts` opinion, the judgment matrix $A$ is formed, $A = (a_{ij}), a_{ij} > 0, a_{ji} = 1/a_{ij}, a_{ii} = 1$, where $i = 1,...,m$, $j = 1,...,m$, $m=3$ is a number of alternatives, and $a_{ij}$ is a ratio of the importance of one alternative over another. The evaluations of each expert (number of experts $f$=4) form pair-wise comparison matrixes (Table 3). For every matrix, each column of the matrix is normalized, the sum of each line is divided in $m$, and the achieved vector $w$ is a priority vector (Table 4).

TABLE 1. THE CRITERIA IN DESIGNED AHP

| Notation | Criterion |
|---|---|
| $C_1$ | the compliance with other products and services |
| $C_2$ | the compliance of the application with content accessibility demands |
| $C_3$ | the ease of navigation in an application |
| $C_4$ | the person-adjustment level of an application |

TABLE 2. ALTERNATIVE APPLICATIONS

| Notation | Alternative application |
|---|---|
| $A_1$ | Smart Closet |
| $A_2$ | Your Closet – Smart Fashion |
| $A_3$ | Lookbook |

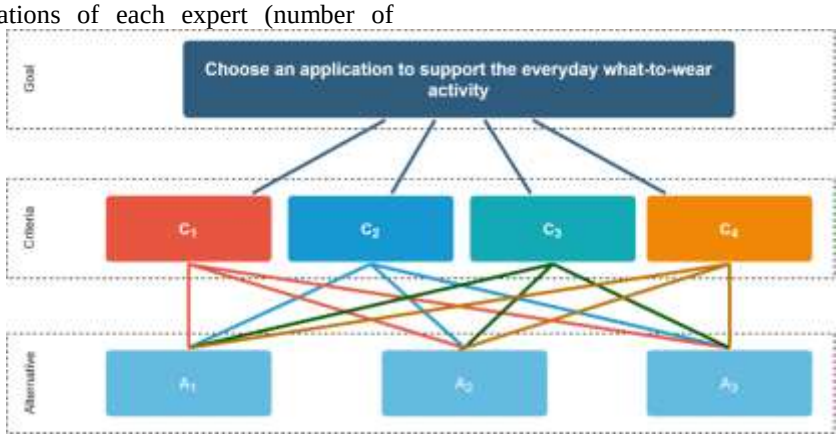

Fig. 4: Decision hierarchy

TABLE 3. THE PAIR-WISE COMPARISON MATRIXES

| | Criteria | | | |
|---|---|---|---|---|
| | C1 | C2 | C3 | C4 |
| Expert 1 | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 4 & 6 \\ 1/4 & 1 & 2 \\ 1/6 & 1/2 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1/4 & 1 \\ 4 & 1 & 4 \\ 1 & 1/4 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1/9 & 1 \\ 9 & 1 & 7 \\ 1 & 1/7 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 8 & 2 \\ 1/8 & 1 & 1/2 \\ 1/2 & 2 & 1 \end{bmatrix}$ |
| Expert 2 | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 2 \\ 1/2 & 1/2 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 7 & 5 \\ 1/7 & 1 & 1/2 \\ 1/5 & 2 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1/9 & 2 \\ 9 & 1 & 9 \\ 1/2 & 1/9 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1/3 & 1 \\ 3 & 1 & 2 \\ 1 & 1/2 & 1 \end{bmatrix}$ |
| Expert 3 | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1/2 & 5 \\ 2 & 1 & 9 \\ 1/5 & 1/9 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 3 & 1 \\ 1/3 & 1 & 1/4 \\ 1 & 4 & 1 \end{bmatrix}$ |
| Expert 4 | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1 & 7 \\ 1 & 1 & 3 \\ 1/7 & 1/3 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 5 & 5 \\ 1/5 & 1 & 2 \\ 1/5 & 1/2 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 2 & 2 \\ 1/2 & 1 & 1/2 \\ 1/2 & 2 & 1 \end{bmatrix}$ | $\begin{matrix} A_1 & A_2 & A_3 \end{matrix}$<br>$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1/2 & 1 \end{bmatrix}$ |

The main eigenvalue λ is used to determine the consistency of experts` opinions. To do so, the elements of each column of pair-wise comparison matrix should be summed, and the λ is calculated by multiplying the found vector of sums with *w*. The judgements are more consistent, the closer λ is to the rank of the pair-wise comparison matrix. The consistency index $CI = \frac{\lambda - m}{m-1}$ is then used to calculate the consistency ratio *CR*: the random consistency index *RI* (Table 5) is found, according to the rank of pair-wise comparison matrix, $CR = \frac{CI}{RI}$. When the consistency ratio is less than 0.1, it is considered as the matrix meets the consistency standards (Table 6).

TABLE 5. RANDOM CONSISTENCY INDEX (M IS THE RANK OF THE MATRIX A)

| *M* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| *RI* | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

TABLE 6. CONSISTENCY RATIOS OF THE PAIR-WISE COMPARISON MATRIXES (FROM TABLE 3)

| | Criteria | | | |
|---|---|---|---|---|
| | C1 | C2 | C3 | C4 |
| Expert 1 | 0,013 | 0 | 0,012 | 0,069 |
| Expert 2 | 0,052 | 0,021 | 0,095 | 0,019 |
| Expert 3 | 0 | 0,002 | 0 | 0,010 |
| Expert 4 | 0,090 | 0,076 | 0,052 | 0,048 |

The relative priority vector contains an overall evaluation of the alternatives, and in this research, we calculate relative priority as average for each alternative.

## 4. Make decision

According to Relative priority from Table 4, experts` evaluation differs. Thus, Expert 1, Expert 2, and Expert 3 suggest Alternative 2 to be the most relevant, but Expert 4 tends to name Alternative 1 as the best. By calculating the Average of Relative priorities (Table 4), it is difficult to distinguish between Alternative 1 and Alternative 2. To make a final decision, an additional technique should be used. As the next step, the authors suggest implying the decision under uncertainty approach. In such case, we analyze the experts` evaluations to make a decision, which expert seems to be the most reliable and then accept his/her decision.

## INTELLECTUAL INFORMATION SYSTEM CONCEPT

The main functions of the information system to support the wardrobe completion decision are presented in the form of use case diagram (UML). To represent the main relationship between the user and the precedents provided by the intelligent information system, a diagram of precedents was constructed (Fig. 5).

TABLE 4. THE PRIORITY VECTORS OF THE PAIR-WISE COMPARISON MATRIXES (FROM TABLE 3)

| | Criteria | | | | Relative priority | Average relative priority |
|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | | |
| Expert 1 | $w \begin{bmatrix} 0.700 \\ 0.194 \\ 0.107 \end{bmatrix}$ | $w \begin{bmatrix} 0.167 \\ 0.667 \\ 0.167 \end{bmatrix}$ | $w \begin{bmatrix} 0.097 \\ 0.798 \\ 0.105 \end{bmatrix}$ | $w \begin{bmatrix} 0.638 \\ 0.104 \\ 0.258 \end{bmatrix}$ | $w \begin{bmatrix} 0.400 \\ 0.440 \\ 0.159 \end{bmatrix}$ | $w_{avg} \begin{bmatrix} 0.40075 \\ 0.39375 \\ 0.20600 \end{bmatrix}$ |
| Expert 2 | $w \begin{bmatrix} 0.312 \\ 0.490 \\ 0.198 \end{bmatrix}$ | $w \begin{bmatrix} 0.738 \\ 0.094 \\ 0.168 \end{bmatrix}$ | $w \begin{bmatrix} 0.118 \\ 0.808 \\ 0.074 \end{bmatrix}$ | $w \begin{bmatrix} 0.211 \\ 0.548 \\ 0.241 \end{bmatrix}$ | $w \begin{bmatrix} 0.345 \\ 0.485 \\ 0.170 \end{bmatrix}$ | |
| Expert 3 | $w \begin{bmatrix} 0.333 \\ 0.333 \\ 0.333 \end{bmatrix}$ | $w \begin{bmatrix} 0.319 \\ 0.615 \\ 0.066 \end{bmatrix}$ | $w \begin{bmatrix} 0.333 \\ 0.333 \\ 0.333 \end{bmatrix}$ | $w \begin{bmatrix} 0.416 \\ 0.126 \\ 0.458 \end{bmatrix}$ | $w \begin{bmatrix} 0.350 \\ 0.352 \\ 0.298 \end{bmatrix}$ | |
| Expert 4 | $w \begin{bmatrix} 0.511 \\ 0.389 \\ 0.100 \end{bmatrix}$ | $w \begin{bmatrix} 0.703 \\ 0.182 \\ 0.115 \end{bmatrix}$ | $w \begin{bmatrix} 0.490 \\ 0.198 \\ 0.312 \end{bmatrix}$ | $w \begin{bmatrix} 0.328 \\ 0.411 \\ 0.261 \end{bmatrix}$ | $w \begin{bmatrix} 0.508 \\ 0.295 \\ 0.197 \end{bmatrix}$ | |

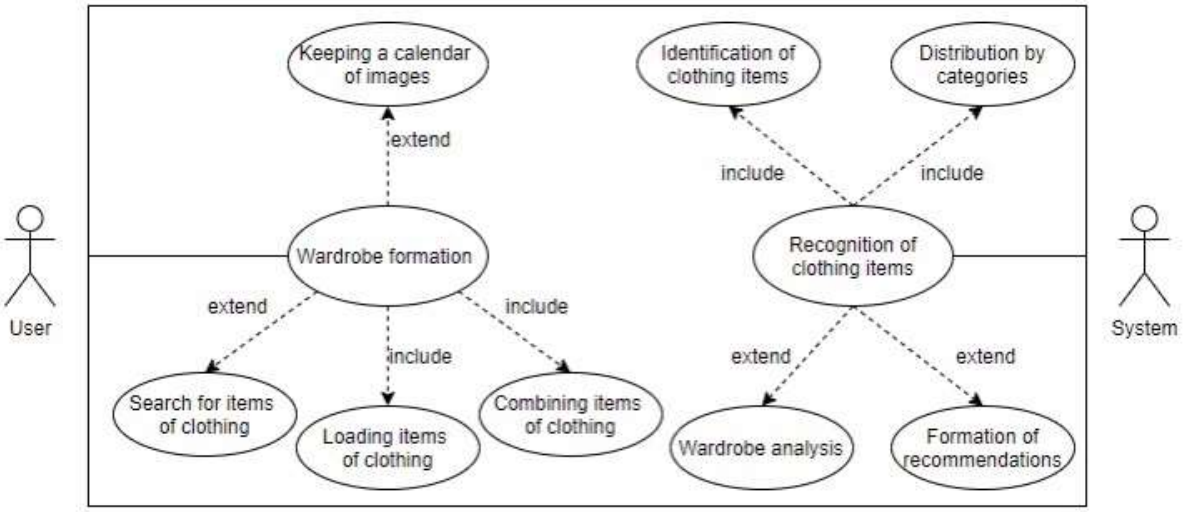


Fig.5. Use Case diagram

Two main actors were identified:

- User, a person who is a consumer of this software product;
- System, a developed intelligent information system.

The actors connected to a system of wardrobe completion to satisfy their needs and support the system`s functions as follows.

- *Search for items of clothing*, *Keeping the calendar of images* are connected with *Wardrobe formation* by the type of relationship *extend*, i.e. expand the latter;
- *Loading items of clothing*, *Combining items of clothing* are connected with *Wardrobe formation* by type include of the relationship, i.e. the first two are included in the latter;
- *Identification of clothing items*, *Distribution by categories* are connected with *Recognition of clothing items* by the type of relationship *include*, i.e. the first two are included in the latter;
- *Wardrobe analysis*, *Formation of recommendation* are connected with *Recognition of clothing items* by the type of relationship *extend*, i.e. extend the latter.

To form a recommendation for the daily outfit, the artificial intelligence approach is suggested.

## CONVOLUTIONAL NEURAL NETWORK AS RECOMMENDER SYSTEM ENGINE

Interest in image recognition shows a tendency to increase over time because of the wide range of possibilities of its result application [10-13]. Fashion, one of the rapidly growing industries has, its own special demands and purposes to image recognition in precise, and information technologies in general, application. In [14], a scientific and practical task to create a fully animated digital double was described, to do so, one needs an RGB camera. The created double can be used to virtual try-on for online fashion shopping. Authors in [15] considered the problem of detecting objects from videos in an online fashion and described an approach to increase the detection accuracy level. The Mobile Augmented Reality (MAR) technology claimed to be the key concept in the Fashion Retail Industry, as it has great potential to improve the shopping experience of consumers in multiple fashion-related industry directions [16]. The attempts to create a recommender system that would generate fashionable outfits were made in [17, 18].

Neural networks are successfully used in solving many problems of pattern recognition [19]: character recognition, object recognition, and many others. Currently, classical neural network architectures (multilayer perceptron, networks with radial basis function, convolutional neural networks, etc.) are most often used in image recognition and identification tasks.

The convolutional neural network systems are widely used to solve classification tasks, for example, in game genre classification [20], multi-object detection in sports competition [21], mental states monitoring [22], harvest evaluation [23], mind wandering [24], gesture or emotion recognition [25, 26], acoustic scene classification [27], computer tomography results evaluation [28], etc.

After being trained, the CNN net converts an image from RGB into grayscale, and after proper calculation and comparison, forms the conclusion, which least different from the template.

## CONCLUSIONS

Visual perception is one of the most important sources of information, therefore the main tasks solved in modern information systems include letter recognition, mathematical symbols, words, phrases, identification by photo or fingerprints, sign language recognition, etc. An important meaning has an automated possibility to recognize a photo, identify or locate an object in an image, recognize information that contains an object, and so on. One of the applications of such technologies is digital fashion, namely in wardrobe completion. On analyzing the

existing applications, their functionality, advantages, and disadvantages were studied. The application of the method of hierarchy analysis process allowed us to make a decision about the best application to support the process of choosing a wardrobe, however, the results showed the need to use additional methods to support decision-making. In the future, it is planned to use the decision-making approach in conditions of uncertainty.

The system analysis of the object of the study identified the main tasks to be solved by the system. After the analysis, it was determined that the topic is relevant for implementation and will be in demand among potential users, as existing solutions do not allow for rational and automated design of the wardrobe, which is one of the key functions of the system. A Use Case diagram was used to structure the proper intellectual information system of wardrobe formation.

A detailed review of methods for solving computer vision problems showed that it is advisable to choose the neural network method to create a system for recognizing clothing details.

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