



## CLASSIFICATION AND EVALUATION OF MATERNITY CLOTHING USING GEOMETRIC INDICES AND MACHINE LEARNING

GOSPODINOVA Mariya<sup>1</sup>, DOLAPCHIEVA Galya<sup>1</sup>, KRASSTEV Krasimir<sup>1</sup>

<sup>1</sup>Trakia University, Faculty of Technics and technologies, 38 Graf Ignatiev str., 8602, Yambol, Bulgaria,

Corresponding author: GOSPODINOVA Mariya, e-mail: [mimoza.1982h@gmail.com](mailto:mimoza.1982h@gmail.com)

**Abstract:** *Maternity apparel constitutes a specific domain within fashion design, necessitating consideration of the intricate physiological and psychological requirements of expectant mothers. The objective of this research is to formulate a systematic classification system for maternity garments, predicated on functional and aesthetic attributes, geometric indices, and machine learning methodologies. A comprehensive analysis was conducted on 32 distinct clothing types and 10 categories of frequently utilized garments; furthermore, 24 geometric indices were extracted from each silhouette to quantify shape, proportions, compactness, and structural features. Feature selection techniques, including FSRNCA, RReliefF, and SFCPP, were employed to ascertain the most pertinent geometric parameters for classification purposes. To categorize clothing into five functional-aesthetic groups, four machine learning algorithms were used: k-nearest neighbors (k-NN), decision tree, ensemble model, and support vector machine (SVM) with an ECOC strategy. The ensemble model achieved the highest classification accuracy, reaching 100%, which showed its strong reliability even with small and diverse datasets. The results were validated through expert evaluation by specialists in fashion design, functional apparel, and maternity clothing. This research builds upon current methodologies by combining geometric and semantic attributes, thereby presenting a holistic approach to the assessment and classification of maternity clothing. Moreover, the suggested framework opens avenues for future advancements, such as the integration of three-dimensional body models, personalized garment suggestions tailored to individual body shapes, and intelligent systems designed for the adaptive design of maternity apparel. Consequently, this study enhances comfort, functionality, and aesthetic appeal within the realm of maternity wear, ultimately supporting the well-being and self-assurance of pregnant women across the entirety of their pregnancy.*

**Keywords:** *Functional design, Geometric features, Feature extraction, Machine learning, Classification accuracy, Personalization*

### 1. INTRODUCTION

Clothing design is primarily determined by shape, color, and material, with maternity clothing incorporating contour, construction, and the textiles used [1]. Shapes are important for the style and aesthetics of clothing, with the most commonly used types being A, H, X, T, O, and S [2]. Additional configurations such as “tunic” and “hourglass” expand the classification [3]. These proportions and design solutions correspond to women’s bodies during pregnancy [4]. Contour can highlight or conceal features of the human body [5]. According to Zou et al. [6], the development of fashion design requires international collaboration, multilingual platforms, and innovative technologies that integrate historical and digital perspectives. Research on contours in fashion covers their recognition, cultural significance, and practical application in pregnant women. Jiang et al. [7] developed a method for intelligent recognition of trouser contours using DeepLabV3+, improving accuracy and classification, although with limitations in the variety of poses and clothing. What these studies have in common is more accurate recognition, cultural interpretation, and personalized application of visual configurations in contemporary fashion design. Research on contours in fashion design can be summarized as technologically applied and theoretically cultural.

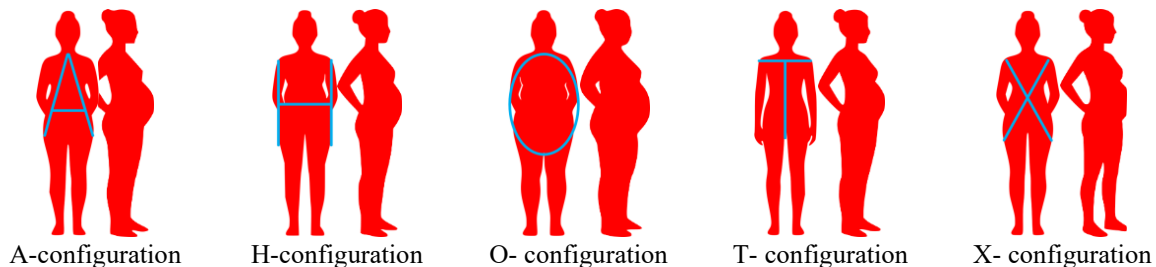
Technological-applied research focuses on automated contour recognition, classification, and optimization using modern digital methods. Zhang et al. [8] used fuzzy C-means and keypoint

positioning algorithms to measure A-shapes in traditional Chinese costumes. Tsuru et al. [9] applied statistical methods such as principal component analysis and cluster analysis to group dresses, while Nie et al. [10] used variance analysis to quantify the factors influencing X-shapes. Lee et al. [11] analyzed over 1,300 images of wedding dresses, classifying their elements as bodices, sleeves, and skirts, which helps designers create fashionable and sought-after models. The presented research focuses on precision, personalization, and efficiency in clothing design and evaluation, primarily in relation to online shopping and digital fashion.

Theoretical-cultural studies encompass classification systems, historical and cultural interpretations of garment outlines, and qualitative methods of analysis. Kazlacheva [12, 13] proposes a detailed classification based on fit, geometric shapes, letter designations, and visual analogies, noting that there is no complete overlap between different classification systems. Hadijah et al. [14] use observation, interviews, and documentation to study the structural details of dresses but are not supported by numerical evidence or statistical analyses that would make them objectively verifiable. Radieva [15] examines the proportions of the lower part of garments at Christian Dior and Cristobal Balenciaga using correspondence analysis, focusing on the influence of design decisions on the overall visual appearance. Indrie et al. [16] complement this line of research by introducing a new classification of combined configurations and applying principal component analysis to more accurately classify garments. These studies prove the cultural, aesthetic, and social value of the outlines of clothing, considering them not only as visual forms but also as carriers of identity, style, and historical heritage.

Pregnancy is a period of significant physiological changes that affect the contours and visual perception of the female body. These transformations lead to a dynamic evolution of characteristic body proportions, which has direct implications for the design and functionality of garments designed for pregnant women.

Figure 1 presents typical contours observed in pregnant women, which are classified by visual categories such as A-, H-, O-, T-, and X-shaped configurations.



*Fig. 1: Visual body configurations during pregnancy*

These categories often overlap with established body types in fashion theory, including pear-shaped, hourglass, apple-shaped, and rectangle-shaped [17]. The A-shaped configuration is associated with wider hips and narrow shoulders, characteristic of early pregnancy, when the pelvic region begins to widen [18]. The H-shaped proportions, with evenly distributed lines, often transform into an O-shaped structure in the later stages of pregnancy due to central volume accumulation [19]. The T-shaped configuration, although less common, is observed in women with an athletic build and may undergo visual changes as gestation progresses [20]. The X-shaped construction, resembling an hourglass, is more stable in early pregnancy but gradually changes as the abdomen grows [21]. The transformations presented are important for the creation of adaptive and aesthetic garments that meet the needs of pregnant women at different stages of gestation. The choice of clothing during pregnancy is a complex process that combines physiological needs and psychosocial factors, reflecting the identity, emotional state, and social role of the woman. Leading criteria in the choice of clothes are comfort, softness of fabrics, and their ability to adapt to body changes.

Figure 2 presents basic outerwear that pregnant women prefer, among which are blouses, shirts, tunics, cardigans, sweaters, sweatshirts, jackets, coats, and blazers, as well as specialized corsets and bustiers. Blouses, shirts, and tunics are usually made of soft and elastic fabrics that provide freedom of movement and easy adaptation to the growing belly and are often distinguished by pleated or loose cuts, creating visual balance and comfort [22]. Cardigans, sweaters, and sweatshirts provide warmth and

layering, which is important during hormonal changes that affect body temperature, while also creating a sense of comfort and protection, which is psychologically significant for the pregnant woman [23]. Jackets and coats, as outerwear, are designed with additional space in the abdominal area and more often include adjustable elements, fulfilling not only a thermal but also a social function, emphasizing the identity of the expectant mother [24]. The jacket and blazer, although less commonly worn, find application in professional environments, adapting through elastic panels or a loose fit, allowing the woman to maintain her professional role and self-confidence [25]. Corsets and bustiers, traditionally associated with body shaping, are used with caution during pregnancy, with medical recommendations limiting their use unless specifically designed to support the back or pelvis, and in some cases corrective belts are used to relieve back pain, but not for aesthetic purposes [26].



*Fig. 2: Clothes more often worn by pregnant women*

Pregnancy is a period of intense physical and emotional changes that require clothing that combines comfort, adaptability, and aesthetics. Maternity clothing influences how a woman perceives her body and feels at different stages of pregnancy. Figure 3 shows the main maternity clothing categories, which are grouped into five categories.

These categories include comfortable and loose cuts such as oversized and cape, adaptive constructions such as wraps and lace-up models, visually balancing designs with pleats and accents around the bust, stable and supportive solutions such as straight and padded structures, and upper construction elements such as sleeves, straps, and polos.

Choosing the right maternity clothing ensures both the physical comfort and psychological well-being of the pregnant woman [4, 17, 27, 28]. Maternity clothes suitable for the entire period of pregnancy combine comfort, adaptability, and visual balance, with the most functional being loose and adjustable shapes. These are A-shaped, trapezoidal, oversized, wrap clothing ("hug me"), as well as models with ties, buttons, or zippers, which provide space in the abdominal area and adapt to the changing dimensions of the body. These designs do not restrict movements, assist thermoregulation, and are also applicable during the breastfeeding period. Maternity clothes with visual accents, such as pleats, gathers, and emphasized lines under or above the bust – create aesthetic harmony and increase the woman's confidence by distracting attention from the areas with the greatest changes. More structural shapes of maternity clothes, such as straight and box, can offer stability and support in the second and third trimesters. Suitable for the entire period of pregnancy are those garments that provide flexibility, comfort, and adaptation, without compromising the personal style and self-esteem of the expectant mother.

The review of available literature sources shows that research is mainly focused on visual classification, cultural interpretation, and automated recognition, but to a lesser extent they take into account the specific physiological and psychological needs of the pregnant woman. There is a lack of an integrated approach that combines aesthetics, functionality, and quantitative assessment of clothing

related to pregnancy. This necessitates the development of a systematic methodology for the classification and assessment of clothing for pregnant women, which would reflect the real requirements of this consumer segment and support the creation of adaptive and comfortable design.



*Fig. 3: Clothes for pregnant women*

The aim of this work is to systematize the classification of clothing for pregnant women, based on functional and aesthetic criteria, geometric indices, and machine learning algorithms. It is necessary to identify appropriate clothing that meets the physiological and psychological needs of women during pregnancy and after childbirth.

## 2. MATERIAL AND METHODS

The classification of maternity clothing includes coded designations, grouping by functional and aesthetic criteria, and evaluation with geometric indices. Feature selection and machine learning methods were used to determine the informativeness and accuracy of the classification. Table 1 shows the designations of maternity clothing. Each garment is designated by a code (CS1–CS32) and a short name reflecting its design features and decorative elements.

*Table 1: Designations of clothing for pregnant women*

№	Name	№	Name	№	Name	№	Name
CS1	A-line	CS9	Box	CS17	Underbust	CS25	With belt
CS2	Asymmetrical	CS10	Pleated	CS18	Padded	CS26	With straps
CS3	Strapless	CS11	Above Bust	CS19	Sleeve	CS27	With sleeves
CS4	Bomber	CS12	Cloak	CS20	Straight	CS28	With front zipper
CS5	Ruffles and Drapery	CS13	Unlined	CS21	Wrap	CS29	Free



CS6	Double Breasted	CS14	Oversized	CS22	Slim	CS30	Short
CS7	Vest-Dress	CS15	Peplum	CS23	Hourglass	CS31	Trapezoidal
CS8	Corset	CS16	Slim-Fit	CS24	Tie-front	CS32	Extended

Table 2 shows the designations of garments more often worn by pregnant women. The suitability of these garments for pregnant women, such as blouses, tunics, vests, and coats, is explained by their ability to adapt to anatomical changes during pregnancy, providing comfort, freedom of movement, and ease of dressing. On the other hand, corsets and tight-fitting clothes are less used, as they restrict movement, do not allow expansion of the volume around the abdomen, and can cause discomfort or even pain.

*Table 2: Clothing designations more often worn by pregnant women*

N <sub>2</sub>	Name	N <sub>2</sub>	Name
A1	Blouses	A6	Sweatshirts
A2	Shirts	A7	Corsets
A3	Tunics	A8	Jackets
A4	Vests	A9	Jackets
A5	Sweaters	A10	Coats

The criteria described in Table 3 were used to group maternity clothing. These criteria were used to classify garments according to their functionality and aesthetics from a pregnancy perspective. Each group (G1–G5) reflects a specific aspect of design—from physical comfort and adaptability to body changes to visual balance, structural support, and stability in the upper body. A brief description of each group, typical construction and decorative elements, as well as the main function that the given criterion performs in supporting the needs of a woman during the different stages of pregnancy and postpartum, is provided.

*Table 3: Criteria for grouping clothing for pregnant women*

N <sub>2</sub>	Criteria	Description	Typical elements	Main function
G1	Comfort and freedom	Space and movement	Loose fit, oversized, capes, cardigans, bombers	Physical comfort and thermoregulation in the 2nd and 3rd trimesters
G2	Adaptability	Adjustment to body changes	Wrap cuts, ties, buttons, zippers, belts	Flexibility during pregnancy and postpartum (incl. breastfeeding)
G3	Visual balance	Harmony and aesthetic deviation	Asymmetry, ruffles, pleats, under/over bust accents	Supports a woman's self-esteem, diverts attention from areas of change
G4	Structural support	Support and visual design	Corset and straight shapes, box silhouette, belts, lining	Posture support
G5	Upper structure	Upper comfort and stability	Straps, sleeves, polo collars	Provides comfort, style and stability in the chest and neck area

The typical garments for pregnant women were grouped by three specialists in the subject area independently of each other. They have diverse but complementary professional experience in the field of fashion design, with a focus on adaptive and functional design, medicine, and the trade of maternity clothing.

A total of 24 coefficients per object in an image were used [29]. The coefficients (K1-K24) can be grouped according to the geometric and metric characteristics they describe. Groups K1, K3, K4, K5, K6, and K15 include coefficients related to the ratio between the perimeter (P) and the area (A) of the figure, which is an indicator of compactness and deviation from the ideal shape. Groups K2, K10, K16, K18, and K20 contain coefficients based on the ratio between the major and minor axes of the garments (D and d), expressed as dimensionless ratios. Groups K7, K9, K11, K12, and K14 describe differences and ratios between D and d, using combined or transformed relationships, including roots and polynomials. Groups K13, K19, K21, K23, and K24 describe the relationship between diameters and perimeter, estimating external density or extensibility. Finally, K22 uses volume (V) together with diameters, thus presenting a sufficiently detailed assessment of clothing.

The geometrical clothing coefficients (indices) have the form:



$$\begin{aligned}
 K_1 &= \frac{P^2}{A} & (1) & & K_9 &= \left(\frac{D}{2} - \frac{d}{2}\right) \frac{D}{d^2} & (9) & & K_{17} &= \frac{D}{d} - 1 & (17) \\
 K_2 &= \frac{D}{d} \cdot 100, \% & (2) & & K_{10} &= \frac{d}{D} - 1 & (10) & & K_{18} &= \frac{D}{d} & (18) \\
 K_3 &= \frac{P^2}{4\pi A} & (3) & & K_{11} &= \frac{\left(\frac{D}{2} - \frac{d}{2}\right)}{d} & (11) & & K_{19} &= \frac{dD}{2} & (19) \\
 K_4 &= \frac{1}{K_3} & (4) & & K_{12} &= \frac{D-d}{D} & (12) & & K_{20} &= \frac{D-d}{2d} & (20) \\
 K_5 &= \frac{A}{A_{ideal}} & (5) & & K_{13} &= \frac{dD}{2} - 1 & (13) & & K_{21} &= \frac{P}{D} & (21) \\
 K_6 &= \frac{A}{A_{mr}} & (6) & & K_{14} &= \frac{(D+2)(d+2)}{2D^2(-dD+D+2)} & (14) & & V &= \frac{4}{3}\pi \frac{D}{2} \left(\frac{d}{2}\right)^2 & (22) \\
 K_7 &= \left(\sqrt{\frac{D}{2}} + \sqrt{\frac{d}{2}}\right) \sqrt{\frac{D}{2}} \frac{1}{d} - 1 & (7) & & K_{15} &= \frac{P^2}{4\pi A} - 1 & (15) & & K_{22} &= \frac{3V}{4\pi D d^2} & \\
 K_8 &= \frac{\frac{d}{2}}{\frac{D}{2}} & (8) & & K_{16} &= \frac{d}{D} & (16) & & K_{23} &= \frac{P}{D-P} & (23) \\
 & & & & & & & & K_{24} &= \frac{D}{D-P} & (24)
 \end{aligned}$$

where  $d$  is the minor axis of the garment;  $D$  is the major axis of the garment;  $P$  is the perimeter;  $A$  is the area;  $A_{ideal}$  is the ideal area calculated along the major and minor axes of the garment;  $A_{mr}$  is the area of the rectangle enclosing the garment;  $V$  is the volume calculated along the major and minor axes.

The informativeness of the clothing indices for pregnant women was determined using the FSRNCA, RreliefF, and SFCPP selection methods. FSRNCA (Feature Selection for Classification and Regression by Neighboring Component Analysis). This method identifies the most appropriate clothing indices obtained in such a way as to minimize the prediction error [30]. RReliefF is used for feature selection in regression tasks. It evaluates the importance of features based on their ability to distinguish data that are close to each other [31]. This algorithm is suitable for assessing the significance of features for distance-based models. SFCPP (Selection of Features with Comparable Predictive Power). A feature selection method that identifies features with similar predictive power while reducing data redundancy [32]. Informative indices are those that have weighting coefficients with a value above 0,6 [33].

To group the maternity clothes into the five proposed groups, based on their shape indices, the following classification methods were used: k-NN, Decision Tree, Ensemble method and SVM. The k-nearest neighbor (k-NN) method is not complex, but it is a sufficiently effective classifier that classifies an object according to the set of its k-nearest neighbors in the feature space. It is suitable for small to moderate-sized data sets, where a long training process is not required [34]. The decision tree is a widely used method due to its interpretability, ability to process both numerical and categorical data, and sufficiently good efficiency for moderate-sized data sets. It represents a hierarchical structure, which facilitates the visualization of the classification process [35]. The ensemble method combines multiple weak classifiers (e.g. decision trees) into a single strong model, improving accuracy and robustness on small and noisy datasets. The method reduces variance through techniques such as Bagging and Boosting. Especially for more complex class boundaries, ensemble models have significantly better performance compared to single classifiers [36]. Multiclass SVM with ECOC strategy. The fitcecoc function in MATLAB implements the Error-Correcting Output Codes (ECOC) approach for multiclass classification by binarizing the problem and using binary classifiers as SVMs. The method is efficient on a large number of classes and shows reasonably good robustness against noise [37].

The classification accuracy is estimated by the following formula:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \times 100, \% \quad (25)$$



where TP (True Positive) The model correctly predicts a positive class; TN (True Negative) The model correctly predicts a negative class; FP (False Positive) The model incorrectly predicts a positive class; FN (False Negative) The model incorrectly predicts a negative class; TP+TN are the correctly classified data; FP+FN are the incorrectly classified data.

## 12. RESULTS

An analysis was made of the possibility of combining garments more often worn by pregnant women and the types of garments into which they can be made. Table 4 presents the average ratings of three specialists in the subject area, on a scale from 1 to 5. "0" marks the combinations of clothes that, according to the specialists, are not recommended for wearing by pregnant women. According to the results presented by the specialists in the subject area, the lower ratings for some of the combinations of clothes for pregnant women are due to several factors. Combinations with low ratings (e.g., CS3, CS8, CS16, CS23, CS30) refer to clothes that are not suitable during pregnancy, as they restrict movement, tighten the body, or are not functional. For example, corsets (CS8) or tight-fitting clothes would be extremely uncomfortable and unhealthy for the growing belly. Lower scores for other combinations (e.g., CS4, CS6) may be explained by decreasing comfort during different stages of pregnancy, where clothes that were suitable at the beginning become impractical later. At the same time, high scores (5) for combinations such as CS1, CS2, CS5, CS9, and CS10 are given to versatile and comfortable garments, such as A-line loose tunics, expandable shirts, or oversized sweaters, which provide space and comfort throughout the pregnancy.

A grouping of maternity clothing was made by three specialists in the subject area. The results are presented in table 5. In all cases, the specialists have the same opinion about the groups in which the clothing falls, except for GS11, which according to two of the specialists falls into group G3, and according to the third, falls into group G5. This clothing is placed in group G3.

The groups into which maternity clothing is distributed were used as the basis for the selection of informative indices. The results of this selection are shown in Figure 4. Table 6 presents the selected clothing indices for pregnant women. Using the FSRNCA method, 9 indices were selected, which have weight coefficient values above 0.6. Using the RreliefF method, 7 of them are informative. Using the SFCPP method, the most were selected compared to the other methods – a total of 10 clothing indices.

The misclassified data are shown in red and bold. In this method, the best results compared to the others are achieved by the ensemble model, which classifies all garments correctly—100% accuracy. SVM also performs stably with fewer errors, while Decision Tree and especially k-NN show significantly lower accuracy. kNN allows 17 errors, making it the weakest model. The results show that the FSRNCA-selected garment indices can be used effectively when processed with ensemble approaches, but not so much with simpler models such as k-NN.

**Table 4:** Averaged assessments of specialists in the subject area regarding possibilities for combining clothing more often worn by pregnant women and the types of clothing.

Clothes Types of clothes	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Clothes Types of clothes	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	
	CS1	5	5	5	2	4	2	0	3	5		2	CS17	5	5	5	2	2	2	0	3	3
CS2	5	5	5	3	4	1	0	1	2	1	CS18	0	0	0	0	0	0	0	0	0	3	3
CS3	0	0	0	0	0	0	0	0	0	0	CS19	3	0	0	0	3	1	0	0	0	0	
CS4	0	0	0	0	0	0	0	0	3	2	CS20	5	5	4	3	4	3	2	3	3	3	
CS5	5	4	5	3	4	1	0	3	3	1	CS21	5	5	5	2	3	2	0	3	3	2	
CS6	1	2	0	0	0	0	0	3	3	3	CS22	1	1	0	0	2	2	0	0	0	0	
CS7	0	0	3	3	0	0	0	0	0	0	CS23	0	0	0	0	0	0	0	0	0	0	
CS8	0	0	0	0	0	0	0	0	0	0	CS24	5	5	5	2	3	2	3	3	3	3	
CS9	5	5	5	3	4	3	2	3	4	4	CS25	3	3	3	3	2	2	2	3	3	3	
CS10	5	5	5	3	4	2	0	3	3	1	CS26	2	0	2	0	0	0	0	0	0	0	
CS11	5	5	5	2	2	2	0	3	3	1	CS27	5	5	5	3	4	3	2	3	3	3	
CS12	0	0	0	0	0	0	0	0	3	3	CS28	5	5	5	2	3	2	0	3	3	3	
CS13	5	5	5	3	4	3	0	3	3	3	CS29	5	5	5	3	4	3	0	3	3	3	
CS14	5	5	5	3	4	3	2	3	3	3	CS30	0	0	0	0	0	0	0	0	0	0	
CS15	2	2	3	0	0	0	0	0	0	0	CS31	5	5	5	2	3	3	0	3	3	1	
CS16	0	0	0	0	0	0	0	0	0	0	CS32	5	5	5	3	4	3	0	3	3	3	



Table 5: Grouping of maternity clothing by specialists

Clothes	S1	S2	S3	Total	Clothes	S1	S2	S3	Total
CS1	1	1	1	1	CS17	3	3	3	3
CS2	3	3	3	3	CS18	4	4	4	4
CS3	5	5	5	5	CS19	5	5	5	5
CS4	1	1	1	1	CS20	4	4	4	4
CS5	3	3	3	3	CS21	2	2	2	2
CS6	2	2	2	2	CS22	5	5	5	5
CS7	1	1	1	1	CS23	4	4	4	4
CS8	4	4	4	4	CS24	2	2	2	2
CS9	1	1	1	1	CS25	2	2	2	2
CS10	3	3	3	3	CS26	5	5	5	5
CS11	3	3	5	3	CS27	5	5	5	5
CS12	1	1	1	1	CS28	2	2	2	2
CS13	1	1	1	1	CS29	1	1	1	1
CS14	1	1	1	1	CS30	3	3	3	3
CS15	3	3	3	3	CS31	1	1	1	1
CS16	5	5	5	5	CS32	1	1	1	1

CSx-characteristic maternity clothing; Sx-specialist number

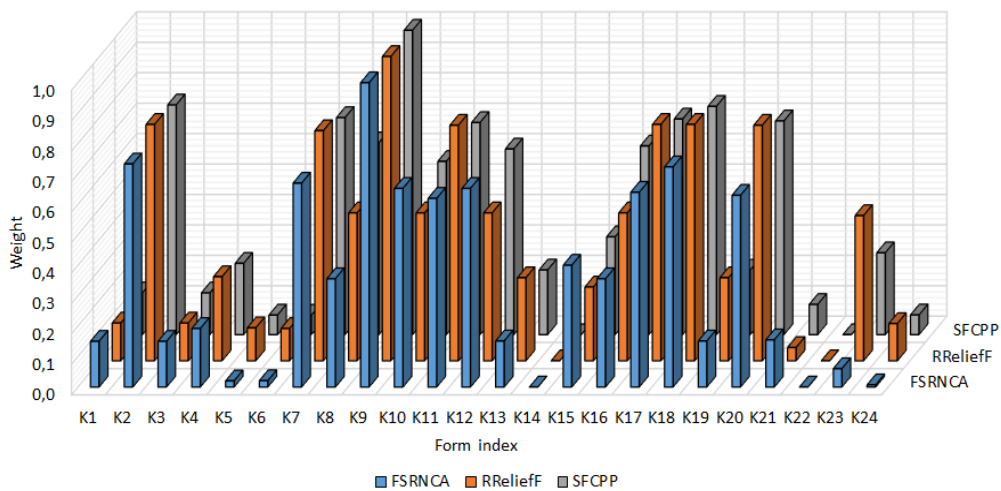
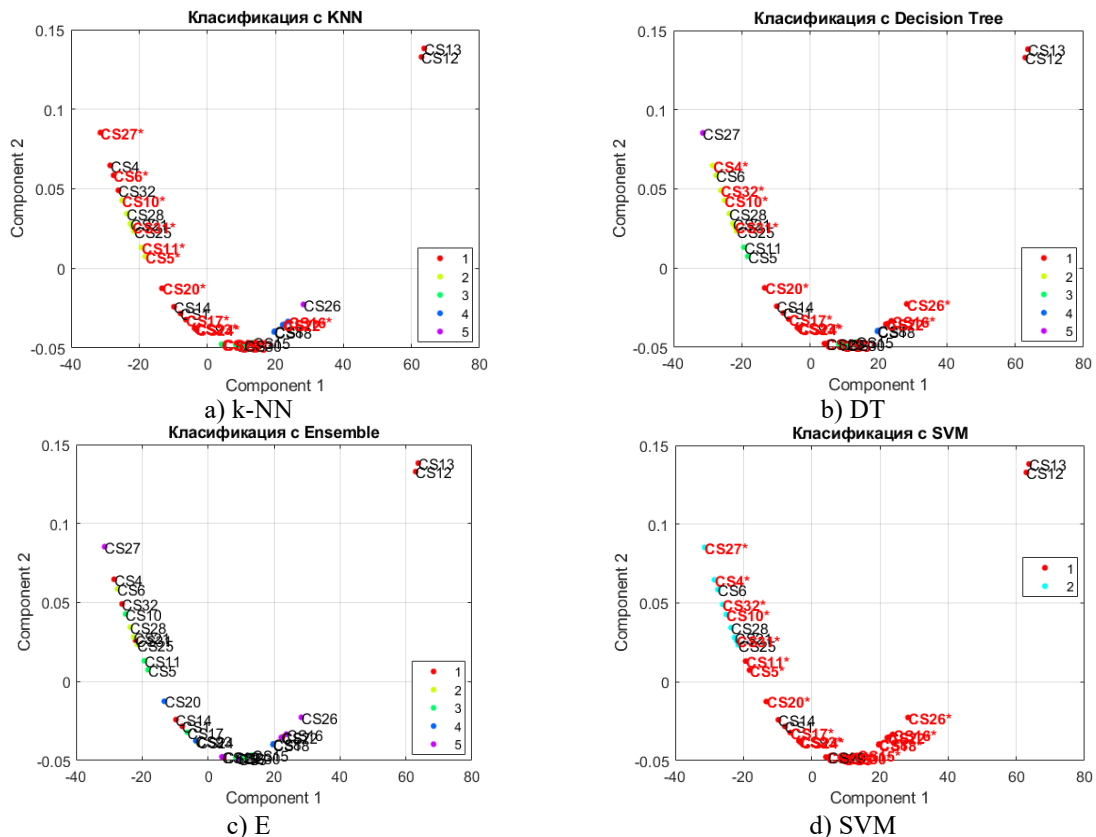


Fig. 4. Results of clothing geometrical index selection for typical maternity clothing

Table 6: Selected clothing geometrical indices relative to typical maternity clothing items

Method \ Index	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
FSRNCA		+					+		+	+	+	+
RRelief		+					+		+		+	
SFCPP		+					+	+	+		+	+
Method \ Index	K13	K14	K15	K16	K17	K18	K19	K20	K21	K22	K23	K24
FSRNCA					+	+		+				
RRelief					+	+		+				
SFCPP				+	+	+		+				

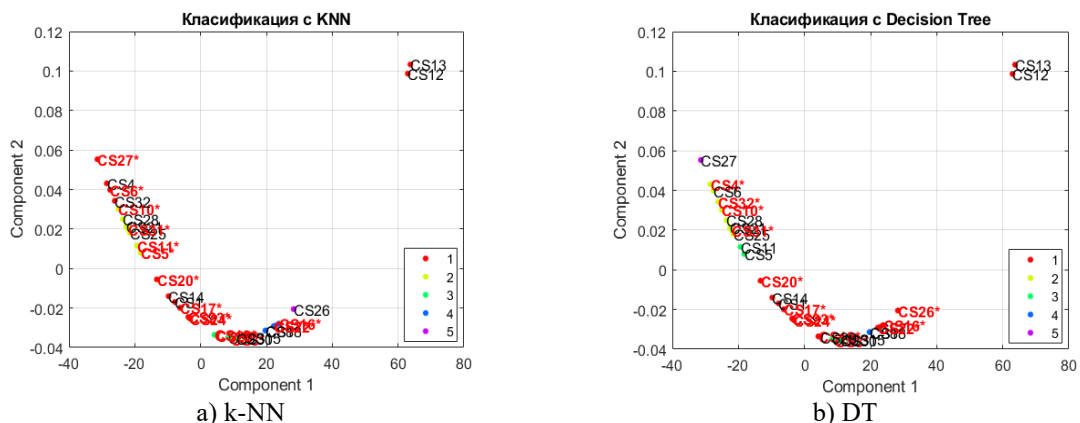
Figure 5 presents the results of classification by a vector of indices selected with the FSRNCA method.

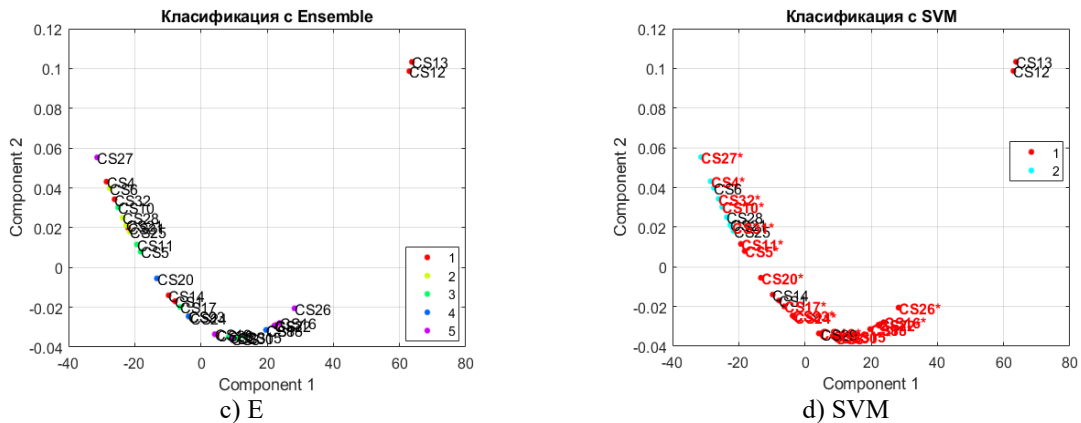


**Fig. 5:** Classification results of clothing geometrical indices selected with FSRNCA method  
*k-NN (k-nearest neighbors); DT-decision tree; E-(Ensemble) Ensemble method; SVM-support vector method*

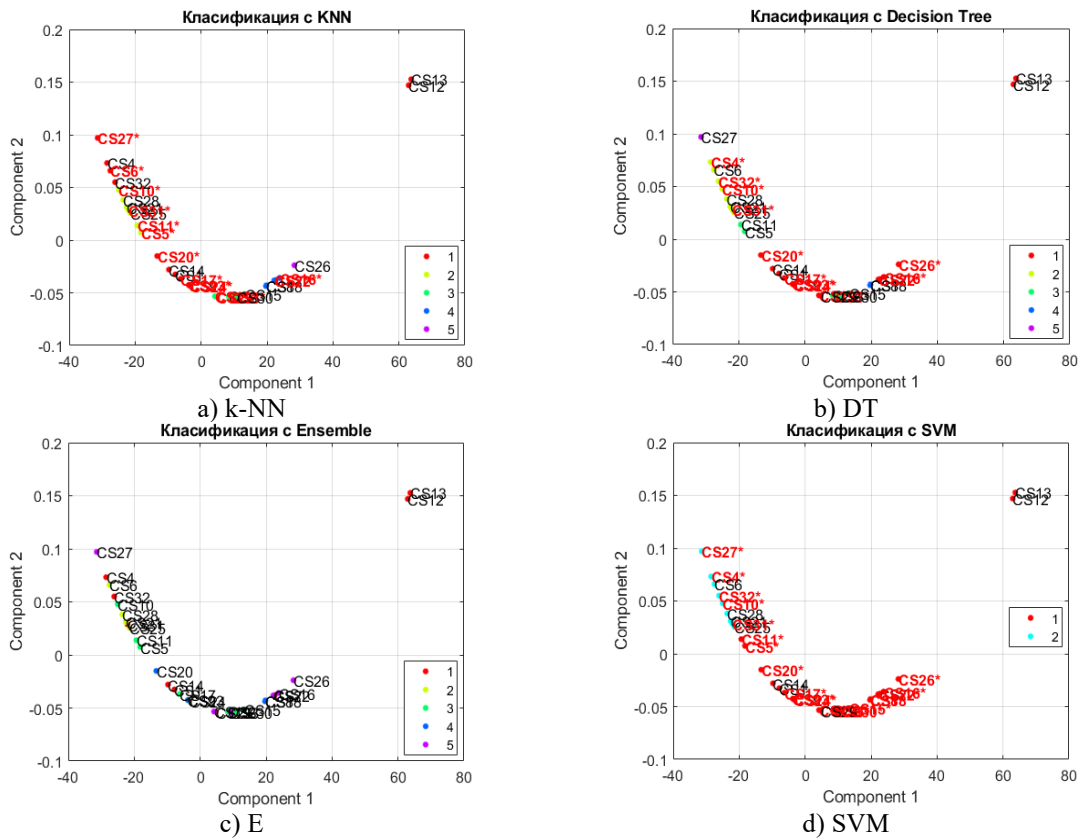
Figure 6 presents the results of classification by a vector of indices selected with the RRelieFF method. Again, the ensemble model stands out with a sufficiently efficient classification – 100% accuracy. SVM and Decision Tree show similar results, with a moderate number of errors, while k-NN again performs the worst. Although RRelieFF manages to extract relevant features, its efficiency strongly depends on the chosen classifier. Ensemble methods make the best use of the selected features, while kNN remains sensitive to noise and class proximity.

Figure 7 presents the results of classification by a vector of indices selected using the SFCPP method. The results using indices selected using SFCPP coincide with those from RRelieFF, which suggests that the selected features lead to a similar differentiation between classes. The ensemble model again demonstrates sufficiently effective classification, while SVM and Decision Tree are of moderate accuracy, and k-NN has the most errors. This shows that SFCPP is a reliable method for index selection, but effective results are achieved only with more complex models that can capture nonlinear dependencies between the data.





**Fig. 6:** Classification results of clothing geometrical indices selected with the method RreliefF  
k-NN-k-nearest neighbors; DT-decision tree; E-(Ensemble) Ensemble method; SVM-support vector method



**Fig. 7:** Classification results by clothing geometrical indices selected with SFCPP method  
k-NN-k-nearest neighbors; DT-decision tree; E-(Ensemble) Ensemble method; SVM-support vector method

Table 7 presents the results of the data clustering, depending on the method for selecting garment indices and the classifier used. The presented results show that the ensemble model (E) achieves the highest accuracy when using indices selected by all three selection methods, classifying all garments correctly. SVM also demonstrates stable results, with a moderate number of misclassified garments, while Decision Tree and especially kNN allow significantly more incorrect classifications. Regardless of the method for selecting garment indices, k-NN shows the lowest efficiency due to being more sensitive to the choice of features and the structure of the data.



Table 7: Results of grouping maternity clothing using classifiers

Clothes	Selection method Classifier Real group	FSRNCA				RReliefF				SFCPP			
		kNN	DT	E	SVM	kNN	DT	E	SVM	kNN	DT	E	SVM
CS1	1	1	1	1	1	1	1	1	1	1	1	1	1
CS2	3	3	3	3	1	3	3	3	1	3	3	3	1
CS3	5	3	3	5	1	3	3	5	1	3	3	5	1
CS4	1	1	2	1	2	1	2	1	2	1	2	1	2
CS5	3	2	3	3	1	2	3	3	1	2	3	3	1
CS6	2	1	2	2	2	1	2	2	2	1	2	2	2
CS7	1	4	1	1	1	4	1	1	1	4	1	1	1
CS8	4	4	4	4	1	4	4	4	1	4	4	4	1
CS9	1	1	1	1	1	1	1	1	1	1	1	1	1
CS10	3	2	2	3	2	2	2	3	2	2	2	3	2
CS11	3	2	3	3	1	2	3	3	1	2	3	3	1
CS12	1	1	1	1	1	1	1	1	1	1	1	1	1
CS13	1	1	1	1	1	1	1	1	1	1	1	1	1
CS14	1	1	1	1	1	1	1	1	1	1	1	1	1
CS15	3	3	3	3	1	3	3	3	1	3	3	3	1
CS16	5	4	1	5	1	4	1	5	1	4	1	5	1
CS17	3	1	1	3	1	1	1	3	1	1	1	3	1
CS18	4	4	4	4	1	4	4	4	1	4	4	4	1

Table 7: Continued...

Clothes	Selection method Classifier Real group	FSRNCA				RReliefF				SFCPP			
		kNN	DT	E	SVM	kNN	DT	E	SVM	kNN	DT	E	SVM
CS19	5	3	1	5	1	3	1	5	1	3	1	5	1
CS20	4	1	1	4	1	1	1	4	1	1	1	4	1
CS21	2	2	2	2	2	2	2	2	2	2	2	2	2
CS22	5	4	1	5	1	4	1	5	1	4	1	5	1
CS23	4	1	1	4	1	1	1	4	1	1	1	4	1
CS24	2	1	1	2	1	1	1	2	1	1	1	2	1
CS25	2	2	2	2	2	2	2	2	2	2	2	2	2
CS26	5	5	1	5	1	5	1	5	1	5	1	5	1
CS27	5	1	5	5	2	1	5	5	2	1	5	5	2
CS28	2	2	2	2	2	2	2	2	2	2	2	2	2
CS29	1	3	1	1	1	3	1	1	1	3	1	1	1
CS30	3	3	3	3	1	3	3	3	1	3	3	3	1
CS31	1	2	2	1	2	2	2	1	2	2	2	1	2
CS32	1	1	2	1	2	1	2	1	2	1	2	1	2

Figure 8 shows the classification accuracy, depending on the method for selecting informative indices of clothing and the classifier used. The results show that the ensemble model (E) achieves 100% accuracy for all selection methods, while kNN and SVM perform significantly worse — with 50% and 34% accuracy, respectively. Decision Tree shows moderate efficiency with 59% accuracy. The figure clearly illustrates that the choice of classifier has a greater impact on the accuracy of clustering than the specific method for feature selection, since the results are identical for all three techniques.

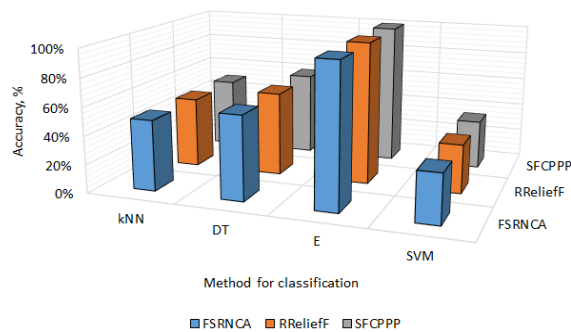


Fig. 8: Accuracy of classification of typical maternity clothing



The analysis of the compatibility between the types of garments preferred by pregnant women, in which they can be made, shows clear dependencies between functionality, stage of pregnancy, and visual structure of the garment. Combinations with high scores (e.g., CS1, CS2, CS5, CS9, CS10) have versatility and adaptability, offering comfort and freedom of movement throughout the gestation period. Combinations with low or zero scores (e.g., CS3, CS8, CS16, CS23, CS30) are characterized by limited functionality, inappropriate constructions, or excessive tightness, making them inappropriate for pregnant women.

The grouping of maternity clothing by experts shows a high degree of consistency, which proves the reliability of visual classification, except for single cases such as CS11, where there is a discrepancy in the opinions of the evaluators. The selection of informative indices of clothing by three different methods (FSRNCA, RReliefF, SFCPP) shows that the most effective results are achieved when using an ensemble model that classifies all garments correctly, regardless of the method for selecting shape indices.

This proves the effectiveness of ensemble approaches—their ability to capture complex, nonlinear dependencies between features. The k-NN method offers the lowest accuracy and high sensitivity to the structure of the data, which makes it unsuitable for tasks with high visual and semantic variability. The accuracy of classification depends more on the model chosen for this purpose than on the specific feature selection method. Ensemble models stand out as reliable when processing visual data of maternity clothing, while simpler algorithms such as k-NN require further optimization or replacement with more robust solutions.

#### 4. DISCUSSION

Unlike theoretical and cultural studies [12, 13, 14, 15], which focus on visual and historical aspects of clothing outlines, the present study combines visual analysis with quantitative geometric indices, which allows for an objective classification and comparison between garments and types of clothing suitable for pregnant women.

This paper further develops the conclusions of Shamsaei et al. [23] and Sun et al. [4] by proposing a structured classification of maternity clothing, taking into account the adaptability, comfort, and aesthetics needed during different stages of pregnancy. The assessments of experts and numerical analyses in the paper objectively show which garments correspond to the needs of the pregnant woman.

This paper uses three methods for selecting informative garment indices (FSRNCA, RReliefF, SFCPP), which build on the approaches of Zhang et al. [8] and Tsuru et al. [9], providing higher informativeness and reducing data redundancy. This leads to more efficient classification and better interpretation of the results.

Compared to Jiang et al. [7], which uses DeepLabV3+ for visual configuration recognition, the present study applies ensemble models that achieve 100% accuracy in classifying maternity clothing. This leads to an improvement in the reliability of the model and its applicability to real data.

While most cited sources consider silhouettes in a general fashion context, the present study focuses entirely on the needs of the pregnant woman. Criteria such as adaptability, comfort, visual balance, and structural support are included, which reflect the real requirements of this specific consumer segment.

#### 5. CONCLUSION

In this work, a structured classification of maternity clothing was made, based on five defined criteria, which cover functionality and aesthetics. Each garment was analyzed using 24 geometric indices, and their informativeness was assessed using three feature selection methods. By applying machine learning algorithms, a sufficiently high accuracy in the classification was achieved (100% in the ensemble method).

From the study of the available literature, it was found that structural elements such as ties, buttons, and zippers contribute to the flexibility of the clothing and facilitate its use both during pregnancy and after childbirth.



It has been proven that certain garments, such as A-shaped, oversized, trapezoidal, and wrap, provide the highest level of comfort and adaptability during the different stages of pregnancy.

Existing theoretical models were supplemented by the introduction of geometric indices of garments, which allow for an objective classification of and assessment of their functionality.

It was found that ensemble machine learning models achieve the highest accuracy in garment classification compared to the other methods, including k-NN, DT, and SVM, making them a reliable tool for analysis.

The integration of geometric indices into digital tools would support the automated assessment of maternity clothing, as well as provide additional validity of the results. The development of adaptive and multifunctional garments, suitable for both pregnancy and the postpartum period, would meet the need for sustainable and personalized design.

## REFERENCES

- [1] M. Pavlova, "Development of boutique denim clothing by the 'upcycling' method," E3S Web Conf., vol. 327, 03002, 2021.
- [2] S. Stangerup, P. Caye-Thomasen, M. Tos, and J. Thomsen, "The natural history of vestibular schwannoma," *Otol. Neurotol.*, vol. 27, no. 4, pp. 547–552, 2006.
- [3] Japan Fashion Education Promotion Association, Fashion Sales 3, Fashion Sales Capability Examination Grade 3 Grade Official Text. Japan Fashion Education Promotion Association, 2018, pp. 102–105.
- [4] Y. Sun and Z. D. Md Nor, "Research on design elements of maternity wear based on the physiological and psychological needs of pregnant women: A narrative review," *Int. J. Heritage, Art Multimedia*, vol. 6, no. 19, pp. 1–12, 2023.
- [5] L. Peters, "You are what you wear: how plus-size fashion figures in fat identity formation," *Fashion Theory*, vol. 18, pp. 45–71, 2014.
- [6] Y. Zou, S. Pintong, T. Shen, and D.-B. Luh, "Evaluation and trend of fashion design research: visualization analysis based on CiteSpace," *Fash. Text.*, vol. 9, p. 45, 2022.
- [7] X. Jiang, Z. Chen, C. Chi, S. Sha, and J. Zhang, "Research on intelligent recognition of trouser silhouettes based on label optimization," *J. Eng. Fiber Fabr.*, vol. 18, pp. 1–9, 2023. doi: 10.1177/15589250231168950
- [8] J. Zhang, J. Wang, L. Xing, and H. Liang, "Automatic measurement of traditional Chinese costume from its silhouette through fuzzy c-means clustering method," *J. Eng. Fiber Fabr.*, vol. 15, 2020.
- [9] T. Tsuru, M. Sugahara, and H. Nishimura, "A classification method for silhouettes of various clothes," in *Proc. ISASE 2019, Fashion Design & Business*, 2019, pp. 1–4, Submission No. C000033.
- [10] Q. X. Nie, Y. Li, and X. G. Wang, "Analysis on influencing factors of X-shape dress silhouette based on eye-tracking technology," *J. Phys. Conf. Ser.*, vol. 1848, 012123, 2021. doi: 10.1088/1742-6596/1848/1/012123
- [11] S. Lee and S. Kwon, "Dress design analysis and pattern making techniques for increasing the efficiency of dress production," *Hum. Ecol. Res.*, vol. 61, pp. 53–71, 2023. doi: 10.6115/her.2023.005
- [12] Z. Kazlacheva, "Silhouettes in the ladies outer garments," *Tekstil Obleklo*, vol. 9, pp. 8–11, 2007.
- [13] Z. Kazlacheva, "Silhouettes of lady's elastomeric clothing," *Tekstil i Obleklo*, vol. 58, no. 1, pp. 12–15, 2010.
- [14] I. Hadijah, E. Prahastuti, and A. D. Astuti, "Analysis of dress pattern of body fitting without waist dart on chiffon fabrics," in *Advances in Social Science, Education and Humanities Research, Proc. 2nd Int. Conf. Vocational Education and Training (ICOVET 2018)*, Fashion Technology Dept., Universitas Negeri Malang, vol. 242, pp. 85–91, 2018.
- [15] K. Radieva, "An investigation of shaping in design of Christian Dior and Cristobal Balenciaga," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1031, 012025, 2021.



- [16] L. Indrie, J. Ilieva, P. Dineva, Z. Kazlacheva, Z. Zlatev, and A. Sturza, "A study of types of silhouettes in women's clothing," *Industria Textila*, vol. 76, no. 1, pp. 19–30, 2025. doi: 10.35530/IT.076.01.2024139
- [17] S. Grogan, *Body image: Understanding body dissatisfaction in men, women and children*, 3rd ed. London: Routledge, 2016. doi: 10.4324/9781315683926
- [18] Z. Sohrabi, A. Kazemi, Z. Farajzadegan, and M. Janighorban, "Body perception in pregnant women: A qualitative study," *BMC Pregnancy Childbirth*, vol. 23, Art. 165, 2023.
- [19] E. B. Salzer, J. F. F. Meireles, A. F. Â. Toledo, M. R. de Siqueira, M. E. C. Ferreira, and C. M. Neves, "Body image assessment tools in pregnant women: A systematic review," *Int. J. Environ. Res. Public Health*, vol. 20, no. 3, p. 2258, 2023.
- [20] T. F. Cash and L. Smolak, *Body image: A handbook of science, practice, and prevention*, 2nd ed. New York, NY: Guilford Press, 2011.
- [21] F. Sterlacci, "Wedge, column, pear and hourglass: 4 body types to know," *University of Fashion Blog*, 2017. Available: <https://www.universityoffashion.com/blog/wedge-column-pear-hourglass-four-body-types-know>. . Accessed: Aug. 3, 2025.
- [22] S. S. Ricci, *Essentials of maternity, newborn, and women's health nursing*, 4th ed. Philadelphia, PA: Lippincott Williams and Wilkins, 2025.
- [23] A. Shamsaei, A. Kazemi, H. Enteshary-Najafabadi, and N. Khosropour Borujeni, "Essential criteria for designing healthy maternity wear: A narrative review," *Iran. J. Nurs. Midwifery Res.*, vol. 27, no. 6, pp. 492–495, 2022.
- [24] M. Nash, *Dressing and Maternity Fashion*, in *Making 'Postmodern' Mothers*, pp. 84–130. Palgrave Macmillan, 2012. doi: 10.1057/9781137292155\_6
- [25] J. P. Ogle and K. E. Tyner, "The role of maternity dress consumption in shaping the self and identity during the liminal transition of pregnancy," *J. Consum. Cult.*, vol. 13, no. 1, pp. 119–139, 2013.
- [26] C. Quintero Rodríguez and O. Troynikov, "The effect of maternity support garments on alleviation of pains and discomforts during pregnancy: A systematic review," *J. Pregnancy*, Article ID 2163790, 2019. doi: 10.1155/2019/2163790
- [27] A. Jaiswal, "Smart motherhood wear: A solution to the problem of maternity wear," *Int. J. Home Sci.*, vol. 8, no. 1, pp. 278–281, 2022.
- [28] M. S. Rasel and J. Sarkar, "Maternity clothing: A comprehensive review," *Dept. Textile Eng., KUET, Bangladesh*, 2017. Available: [https://www.researchgate.net/publication/320443178\\_Maternity\\_Clothing\\_A\\_comprehensive\\_Review](https://www.researchgate.net/publication/320443178_Maternity_Clothing_A_comprehensive_Review)
- [29] I. Mytiai and A. Matsyura, "Mathematical interpretation of artificial ovoids and avian egg shapes (part I)," *Regul. Mech. Biosyst.*, vol. 10, pp. 92–102, 2019.
- [30] FSRNCA, "Feature selection using neighborhood component analysis for regression," *MathWorks*, Online. Available: <https://www.mathworks.com/help/stats/fsrnca.html>. . Accessed: Jul. 18, 2025.
- [31] W. Wei, D. Wang, and J. Liang, "Accelerating ReliefF using information granulation," *Int. J. Mach. Learn. Cybern.*, vol. 13, pp. 29–38, 2022.
- [32] SFCPP, "Select Subset of Features with Comparative Predictive Power," *MathWorks*, Online. Available: <https://www.mathworks.com/help/stats/feature-selection.html>. . Accessed: Jul. 26, 2025.
- [33] A. Farrell, G. Wan, S. Rush, J. Martin, J. Belant, A. Butler, and D. Godwin, "Machine learning of large-scale spatial distributions of wild turkeys with high-dimensional environmental data," *Ecol. Evol.*, pp. 1–12, 2019.
- [34] T. Cover and P. Hart, "Nearest neighbor pattern classification," *IEEE Trans. Inf. Theory*, vol. 13, no. 1, pp. 21–27, Jan. 1967. doi: 10.1109/TIT.1967.1053964
- [35] J. R. Quinlan, "Induction of decision trees," *Mach. Learn.*, vol. 1, no. 1, pp. 81–106, 1986. doi: 10.1007/BF00116251
- [36] T. G. Dietterich, "Ensemble methods in machine learning," in *Proc. Int. Workshop Multiple Classifier Systems*, 2000, pp. 1–15. Springer. doi: 10.1007/3-540-45014-9\_1
- [37] T. G. Dietterich and G. Bakiri, "Solving multiclass learning problems via error-correcting output codes," *J. Artif. Intell. Res.*, vol. 2, pp. 263–286, 1995. doi: 10.1613/jair.105