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**«Science & Research
Methodology – 2025»**



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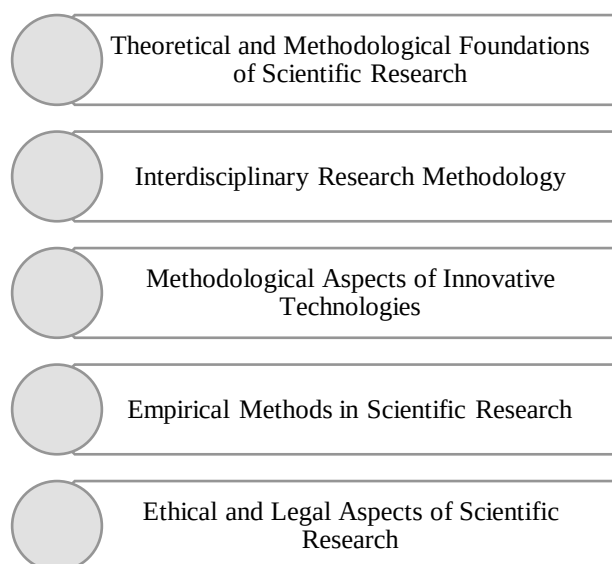


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CONTENTS

<u>Yuliia HEORHII</u>	
DETECTION AND MITIGATION OF AI-DRIVEN ATTACKS	6
<u>Ivan GUZMAN, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
RESEARCH OF THE INERTIAL NAVIGATION SYSTEM	9
<u>Vitalii VIAZOVYK</u>	
FEATURES OF RESEARCH ON OZONE PROCESSES FOR ABSORPTION PURIFICATION OF GASES FROM NITROGEN OXIDES	11
<u>Tymofii PYLYPENKO, Viacheslav TUZ</u>	
UTOMATIC PUMP SPEED CONTROL SYSTEM FOR ACCURATE AND SAFE LIQUID FILLING	14
<u>Yevhenii USENKO, Viacheslav TUZ</u>	
ANALYSIS OF DOMINANT FACTORS AND PHYSICAL MECHANISMS OF INTERLAYER ADHESION IN FDM 3D PRINTING	16
<u>Maksym MANKO, Viacheslav TUZ</u>	
COMPARATIVE ANALYSIS OF CLASSICAL AND QUANTUM ENCRYPTION METHODS FOR SECURE MILITARY COMMUNICATIONS	18
<u>Viktoriia LYTOVCHENKO</u>	
DEVELOPMENT OF A RISK ASSESSMENT SYSTEM AND METHODS FOR MINIMIZING THE IMPACT OF CYBER THREATS IN A REMOTE OFFICE	21
<u>Andrii YAROSLAVSKYI</u>	
DEVELOPMENT OF A COMPUTER PROGRAM FOR MODELING THE ELECTRICAL IMPEDANCE OF A PIEZOELECTRIC CERAMIC TRANSFORMER	24
<u>Oleksandr RYZHAK, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
DEVELOPMENT AND RESEARCH OF ENERGY INSTALLATIONS FOR SENSOR NETWORKS	26
<u>Eduard BED, Viacheslav TUZ, Volodymyr HALCHENKO</u>	
RESEARCH ON FLIGHT ROUTING DEVICES FOR UNMANNED AERIAL VEHICLES	28
<u>Anton PIROGOV, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
STUDY OF THE AUTONOMOUS MECHATRONIC MODULE OF THE CAR CONTROL SYSTEM	30
<u>Vitaly ZAVALNYUK, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
IMPROVING THE QUALITY OF X-RAY DIAGNOSTIC IMAGES IN MATLAB ENVIRONMENT IN AUTOMATIC MODE	32
<u>Artem ANDREOLI, Viacheslav TUZ, Constantine BAZILO</u>	
RESEARCH OF A HYBRID WIND-SOLAR-DIESEL SYSTEM FOR AUTONOMOUS ENERGY SUPPLY	34

<u>Serhii OSADCHYI, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
AUTOMATED SYSTEM FOR CORRECTING MEASUREMENT ERRORS IN LIQUID FLOW METERS	37
<u>Kyrylo YURKIN, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
AUTOMATION OF ELECTRIC SPARK TESTING OF CABLE PRODUCTS	40
<u>Roman BATEKHA, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
RESEARCH ON AN AUTOMATED ACCESS CONTROL SYSTEM BASED ON FINGERPRINT BIOMETRICS	43
<u>Denys PERKIN, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
RESEARCH ON AN AUTOMATIC CONTROL SYSTEM FOR A MANIPULATOR FOR MOVING OBJECTS	45
<u>Vladyslav PRYDATKO, Viacheslav TUZ, Volodymyr HALCHENKO</u>	
AUTOMATED CONTROL SYSTEM FOR VALVE-INDUCTOR DRIVES	47
<u>Liudmyla KOMPANIETS, Viacheslav TUZ, Constantine BAZILO</u>	
AUTOMATION OF NON-INVASIVE HEALTH MONITORING	49
<u>Mykhailo KRASNOKUTSKYI, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
RESEARCH ON A WIRELESS MONITORING SYSTEM FOR SERVO DRIVE PARAMETERS	51
<u>Mykola ONISHCHENKO, Viacheslav TUZ, Volodymyr HALCHENKO</u>	
DEVELOPMENT AND RESEARCH OF AN AUTOMATED GAS CONSUMPTION CONTROL SYSTEM	54
<u>Vitaly ROTAYENKO, Viacheslav TUZ, Ruslana TREMBOVETSKA</u>	
AUTOMATED MEASURING STAND FOR SPACECRAFT CONTROL	56
<u>Olha BASARAB, Maksym BONDARENKO</u>	
RECONSTRUCTION OF SURFACES WITH SCALE-INVARIANT MORPHOLOGY USING ATOMIC FORCE MICROSCOPY	59
<u>Serhii BOHDAN, Constantine BAZILO</u>	
DEVELOPMENT AND RESEARCH OF AN OPTICAL TELEVISION SYSTEM FOR MONITORING AIRSPACE	61
<u>Vitalii CHEREDNICHENKO, Volodymyr HALCHENKO</u>	
DEVELOPMENT AND RESEARCH OF A COMBINED 3D SCANNER WITH PRECISE DETERMINATION OF THE GEOMETRY OF DARK AND TRANSPARENT OBJECTS	63
<u>Ruslan CHUMAK, Maksym BONDARENKO</u>	
COMPARATIVE ANALYSIS OF SCANNING PROBE MICROSCOPY METHODS	66
<u>Andrii STEPANENKO, Constantine BAZILO</u>	
IMPROVEMENT OF PIEZOELECTRIC DRIVE FOR MICRO-ROBOT CONTROL	70

<u>Oleksandr STEPANENKO, Constantine BAZILO</u>	
RESEARCH ON THE INFLUENCE OF TECHNOLOGICAL MODES OF FORMING ANTI-REFLECTION COATINGS ON THEIR OPERATIONAL CHARACTERISTICS	73
<u>Liuba KAMIANSKA</u>	
COMPARATIVE ANALYSIS OF CLASSICAL AND MODERN APPROACHES TO INFORMATION STEGANOGRAPHY	76
<u>Olha ZATORA</u>	
COMPARATIVE ANALYSIS OF STATE SECRET PROTECTION IN UKRAINE AND CANADA	78
<u>Vladyslav FAI, Volodymyr HALCHENKO</u>	
WEAR CONTROL OF HIGH-PRECISION SLIDING ELECTRICAL CONTACTS IN LOW-SPEED APPLICATIONS	80
<u>Maksym SOROKA, Constantine BAZILO</u>	
ULTRASONIC AUTOMATED SYSTEM FOR CONTROLLING THE ORIENTATION OF DETAIL EDGES DURING LASER WELDING	82
<u>Maksym TKACHENKO, Volodymyr HALCHENKO</u>	
CONTROLLED TWO-SIDED CONVECTIVE-BEAM GRAIN DRYING SYSTEM	85
<u>Constantine BAZILO, Maksym BONDARENKO, Liudmyla USYK, Emil FAURE</u>	
AN INTELLIGENT PLATFORM FOR ULTRASONIC ASSISTED EXTRACTION OF PLANT RAW MATERIALS FOR PERSONALISED NUTRIENT SUPPORT	87
<u>Yevgeny KORSHUN, Volodymyr TYCHKOV, Ruslana TREMBOVETSKA, Volodymyr HALCHENKO</u>	
IMPROVING THE EFFECTIVENESS OF ENVIRONMENTAL MONITORING AND PROTECTION OF WATER RESOURCES	89
<u>Dmytro TYCHKOV, Maksym BONDARENKO</u>	
ANALYSIS OF THE INFLUENCE OF EXTERNAL FACTORS ON THE ACCURACY AND RELIABILITY OF MEASUREMENTS OF LOW-INTENSITY ELECTRIC FIELDS USING AN INFORMATION-MEASUREMENT SYSTEM	91
<u>Natalia TYCHKOVA, Volodymyr HALCHENKO, Ruslana TREMBOVETSKA</u>	
DETERMINING EFFECTIVENESS BASED ON THE ACCURACY CRITERION OF THE OPTIMIZATION METHOD FOR RECONSTRUCTING PROFILES IN THE PCA SPACE	93
<u>Oleksandr RUDENKO</u>	
ADAPTIVE OPTIMIZATION OF INDUSTRIAL VENTILATION SYSTEM ENERGY CONSUMPTION BASED ON MODEL PREDICTIVE CONTROL (MPC)	95
<u>Nikon BUGAYCHUK, Volodymyr TYCHKOV, Volodymyr HALCHENKO, Ruslana TREMBOVETSKA</u>	
ROBUST PARAMETRIC DESIGN OF EDDY CURRENT PROBES FOR ACCURATE MEASUREMENT OF MAGNETIC PERMEABILITY IN MOVING FERROMAGNETIC STRIPS USING TAGUCHI OPTIMIZATION	98

<u>Yeqor ANTAS, Oleksandr VASYLKIVSKYI, Oleksandra SEREDA, Ievgen KHYZHNIAK</u>	
REVIEW OF METHODS AND PROSPECTS FOR POST-PROCESSING OF METAL 3D-PRINTED PARTS	100
<u>Heorhii KANASHEVYCH, Yevhenii MALETSKYI, Ihor KOSTIUK, Roman KUSHNIROV</u>	
ETHICO-LEGAL ASPECTS OF DEVELOPING AN ALGORITHM FOR THE OPERATION OF INDIVIDUAL INTELLECTUAL MEDICAL DEVICES – "LAST RESORT" DEVICES IN TACTICAL MEDICINE	102
<u>Oleksandr HREBENIUK, Anton ZHYZHKA, Viktor VASYLCHENKO, Andriy LEGA</u>	
TECHNOLOGIES FOR APPLYING LUBRICANTS AND COOLANTS AND THEIR POTENTIAL IMPACT ON THE WEAR RESISTANCE OF THE WORKING SURFACE OF THE TOOL	105
<u>Volodymyr KOVTUN, Yevhenii ZHYRNYI, Viktor VASYLCHENKO, Oleksandr KOVALENKO</u>	
INVESTIGATION OF THE INFLUENCE OF FUEL OZONATION ON FUEL ACTIVATION	107
<u>Valentin GORDIENKO, Viktor VASYLCHENKO, Vladyslav VYHOVSKYY, Maksym HOLUB</u>	
RESEARCH OF THERMAL COMPENSATION IN OPTOELECTRONIC MODULE	109
<u>Serhii MATSEPA, Yurii KOVALENKO, Maryna YURCHENKO, Andrii MATIUKHA</u>	
MODELS AND METHODS FOR ANALYSIS OF MONITORING DATA OF ELECTRON BEAM PROCESSING OF OPTICAL COMPONENTS	111
<u>Oles STANKEVYCH</u>	
INTELLIGENT SYSTEM FOR THE SMART SORTING OF METALS: A GENERATIVE ADVERSARIAL APPROACH TO SOLVING THE INVERSE PROBLEM	114

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RESEARCH ON AN AUTOMATED ACCESS CONTROL SYSTEM BASED ON FINGERPRINT BIOMETRICS

Abstract. The aim of the work is to investigate existing biometric access control systems and analyze the impact of biometric data comparison algorithms on the system's accuracy, specifically fingerprint identification. The relevance of the topic is determined by the widespread implementation of biometric technologies in security systems (ACS), time tracking systems, as well as in government and financial sectors. The research focuses on the analysis of methods for scanning papillary lines (optical, semiconductor) and comparison algorithms (correlation-based, minutiae-based, pattern-based). The method of Hierarchical Analysis (AHP) was used to choose the optimal component base of the system. Based on the analysis, a mathematical model for fast fingerprint image processing was developed, including the construction of flow and line period matrices, segmentation, filtering using Gabor filters, and skeletonization for minutiae extraction.

Key words: biometrics, access control system (ACS), fingerprint, papillary lines, comparison algorithm, minutiae, Analytic Hierarchy Process (AHP), FAR, FRR.

Introduction. Identity identification is a fundamental task in many areas. Historical methods, such as Bertillonage, proved to be insufficiently reliable. The introduction of fingerprinting (Henry Classification System, 1897) and its subsequent scientific development by Karl Pearson laid the foundation for modern biometrics. Today, biometric systems are used in forensics, security systems, time tracking, as well as in financial and governmental services (ICAO passports, visas). Despite high accuracy, biometric systems face Type 1 errors (FRR - false rejection of a registered user) and Type 2 errors (FAR - false acceptance of an unauthorized user). This is due to the fact that biometric samples are never identical due to varying reading conditions (position, pressure, skin condition). The purpose of this work is to investigate existing biometric systems and fingerprint comparison algorithms to develop a combined algorithm that will increase the accuracy of access control systems.

Methods and Materials. An analysis was conducted on static (fingerprints, iris, hand geometry) and dynamic (voice, handwriting) biometric identification methods. Fingerprint scanning technologies were examined in detail: optical (based on total internal reflection), semiconductor (capacitive, thermal scanners), and ultrasound. Three main types of fingerprint comparison algorithms were analyzed:

- Correlation Comparison: Direct overlay of pixel images. This method is computationally demanding but less sensitive to image quality.
- Minutiae-based Comparison: A template is formed based on the coordinates and orientation of ridge endings and bifurcation points (Fig. 1). This is the most common and fastest method but requires high-quality images.
- Pattern-based Comparison (Texture-based): The image is divided into cells, and the line structure in each is described by sinusoidal wave parameters. This method is complex to implement but fast and less demanding on image quality.

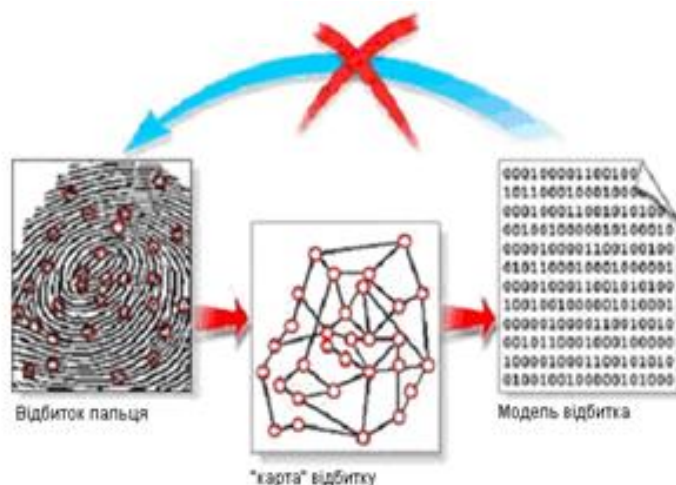


Fig. 1. Formation of a digital template (fingerprint model)

To select the optimal scanner for the developed system, the Analytic Hierarchy Process (AHP) by Thomas Saaty was used. A hierarchical model (Fig. 2) was constructed with the goal of "Selecting the Sensor" and five criteria: FRR, FAR, registration time, identification time, and price. A pairwise comparison of the criteria was conducted, with FAR (0.41) and Price (0.39) being prioritized. Pairwise comparisons of four alternative sensors (S400, 100MA, SR100, U.are.U) were conducted, resulting in the selection of the Sagem 100MA sensor.

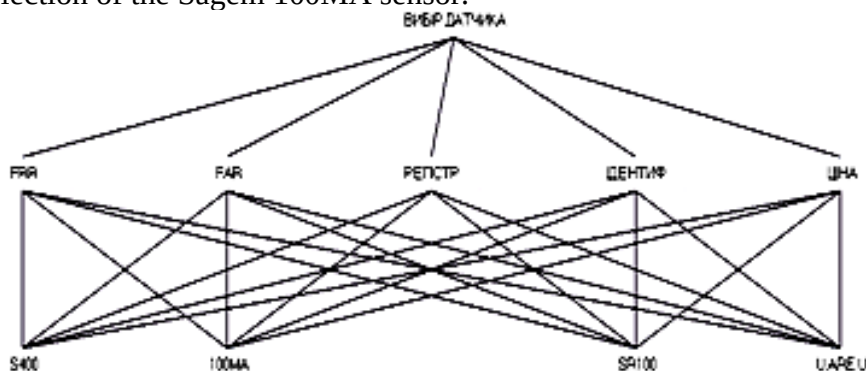


Fig. 2. Hierarchical model for selecting a biometric sensor

A mathematical model for fast image processing was developed for feature extraction. The model includes five stages:

1. Flow Matrix Construction (calculating line orientation using Sobel operators);
2. Line Period Matrix Construction (based on autocorrelation function);
3. Segmentation (to separate informative areas);
4. Filtering (using Gabor filters to remove noise) ;
5. Skeletonization and Minutiae Recognition (endpoints and bifurcations) .

Conclusions. In the course of the work, modern biometric systems were analyzed, along with their advantages and drawbacks. It was determined that fingerprint identification is one of the most widely used, reliable, and accessible technologies. Comparison algorithms (correlation, minutiae-based, pattern-based) were analyzed, forming the basis for the proposal to develop a combined algorithm. Using the Analytic Hierarchy Process, a reasoned selection of equipment for the designed system (Sagem 100MA) was made based on priority criteria (minimal FAR and price). A mathematical model for fast image processing and minutiae extraction was developed, which forms the basis for the software implementation of the biometric access control system.