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CONCEPTUAL AND MATHEMATICAL JUSTIFICATION FOR THE “PETHEALTH” INFORMATION SYSTEM DEVELOPMENT PROJECT

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The article presents the conceptual and mathematical justification for the development of the “PetHealth” information system, designed for centralized management of veterinary services. The study emphasizes the relevance of digital solutions in veterinary medicine, considering the growing number of pets in Ukraine, the introduction of the Unified State Register, and EU requirements for microchipping and vaccination. An analysis of the current market situation revealed that existing services for booking veterinary appointments are fragmented and fail to provide a unified, integrated environment for storing animals’ medical records, which creates difficulties for both pet owners and veterinarians. The proposed “PetHealth” system consolidates key features, including clinic search by geolocation, rating, and price, online appointment scheduling, electronic medical records management, push notifications, online consultations, integrated payment options, and separate profiles for each pet. A conceptual model of the application is presented, outlining its core subsystems (users, clinics, and administration), their interactions, and functional components. A mathematical framework has been developed to formalize system elements, including sets of users, pets, clinics, veterinarians, appointments, medical records, consultations, and transactions. Logical constraints were defined (such as appointment uniqueness, access rights, and payment conditions), along with functions that support core operations such as user registration, pet addition, appointment scheduling, online consultations, and payments. The proposed model ensures data integrity, streamlines interactions between users and clinics, and lays the foundation for practical implementation. The findings confirm the feasibility of implementing “PetHealth” as a unified platform for managing pet health and improving the overall quality of veterinary care.

Key words: *information system, mobile application, conceptual modeling, mathematical modeling, cloud technologies, veterinary services, electronic medical records, digital transformation of veterinary medicine.*

Зюзюн В. І., Даніліна Т. О. Концептуально-математичне обґрунтування проєкту створення інформаційної системи «PetHealth»

У статті представлено концептуальне та математичне обґрунтування проєкту створення інформаційної системи «PetHealth», призначеної для централізованого управління ветеринарними послугами. Робота акцентує увагу на актуальності цифрових рішень у ветеринарії, враховуючи зростання кількості домашніх тварин в Україні, впровадження Єдиного державного реєстру та вимоги ЄС щодо мікрочіпування і вакцинації. Здійснено аналіз сучасного стану ринку: наявні сервіси для запису до ветеринарів є розрізненими та не забезпечують єдиного інтегрованого середовища для зберігання медичних даних тварин, що створює труднощі для власників і лікарів. Запропонована система «PetHealth» об’єднує ключові функції: пошук клінік за геолокацією, рейтингом і ціною, онлайн-запис, ведення електронних медичних карток, push-нагадування, онлайн-консультації,

інтегровану оплату та окремі профілі для кожної тварини. Представлено концептуальну модель додатку, що описує основні підсистеми (користувачі, клініки, адміністрування), їх зв'язки та функціональні компоненти. Розроблено математичний апарат для формалізації елементів системи: множини користувачів, тварин, клінік, ветеринарів, записів, медичних карток, консультацій і транзакцій. Визначено логічні обмеження (унікальність записів, права доступу, умови оплати) та функції для виконання ключових операцій: реєстрації, додавання тварин, створення записів, проведення онлайн-консультацій і платежів. Запропонована модель забезпечує цілісність даних, оптимізує взаємодію між користувачами та клініками й створює основу для програмної реалізації. Результати дослідження доводять доцільність впровадження "PetHealth" як єдиної платформи для управління здоров'ям домашніх тварин і покращення якості ветеринарного обслуговування.

Ключові слова: *інформаційна система, мобільний додаток, концептуальне моделювання, математичне моделювання, хмарні технології, ветеринарні сервіси, електронні медичні картки, цифрова трансформація ветеринарії.*

Introduction. In today's world, pet owners often face challenges when it comes to organizing veterinary care. Despite the existence of various services for finding veterinary clinics and booking appointments, there is still no fully integrated system that brings together all the essential functions needed to conveniently manage pets' health.

In human healthcare, digital platforms such as "Helsi" are widely used, allowing patients to store medical histories, schedule doctor's appointments, receive electronic prescriptions, and get reminders about preventive procedures. In contrast, similar solutions in the veterinary field are either scarce or only partially implemented, which creates significant inconvenience for pet owners. For instance, information about vaccinations, check-ups, lab tests, and veterinary prescriptions is often scattered across multiple sources, making it difficult to keep track of a pet's overall health.

The "PetHealth" project aims to address this issue by creating a comprehensive service for maintaining an electronic medical record for pets, booking veterinary appointments, and quickly locating nearby clinics. This will improve the quality of veterinary care, streamline communication between pet owners and clinics, and simplify the process of storing and managing medical data [1].

In this way, "PetHealth" will serve as a veterinary counterpart to "Helsi", providing a unified platform for effective pet healthcare management.

The aim of the research. To provide a conceptual and mathematical justification for the development of the "PetHealth" mobile application – an information system designed for centralized management of veterinary services, aimed at optimizing the process of locating veterinary clinics, scheduling appointments, and maintaining medical records for pets.

Presentation of the main research material. The modern advancement of digital technologies is transforming the veterinary field, creating new opportunities for efficient management of pet health data and simplifying access to veterinary services. In Ukraine, where there were 5.5 million cats and 750,000 dogs as of 2022 [2], the demand for centralized information systems is steadily increasing. The introduction of mandatory dog registration in May 2025 [3], the launch of the Unified State Register of Pets [4], and the EU requirements for microchipping, rabies vaccination, and pet passports [5] further underscore the need for digital solutions.

However, despite the growing importance of digital tools in veterinary care, most clinics in Ukraine still rely on their own local systems – or even paper records – which complicates the process of finding clinics, scheduling appointments, and maintaining medical records. The absence of a unified system hinders the transfer of information between clinics, often resulting in duplicate records or lost treatment histories. This

creates significant inconvenience for both pet owners and veterinarians, who are left without access to a patient's complete medical history.

The "PetHealth" mobile application, modeled after the "Helsi" platform [6] for human healthcare, is a timely project aimed at creating a unified information system to optimize veterinary services. Just as "Helsi" centralizes medical services by providing convenient access to doctors and electronic medical records, "PetHealth" integrates a wide range of features designed to simplify pet care: an easy-to-use clinic search tool with filters for price, rating, or service type; online appointment booking; electronic medical records with vaccination, microchip, and certification data; push notifications for important events; an integrated payment system for service fees; access to reviews and ratings; and geolocation services for finding the nearest clinics. The app also enables users to create separate profiles for each pet, ensuring convenient, real-time information management. These features enhance clinic efficiency while significantly improving the experience for pet owners.

One of the competitors to the proposed information system is the online platform Vethub [7]. However, it lacks a mobile version, which is a considerable drawback given the realities of today's digital landscape.

"PetHealth" is a mobile application designed for pet owners and veterinary clinics. Its core features include: (1) Clinic search with filters based on geolocation, pricing, ratings, and service types. (2) Online appointment booking with veterinarians. (3) Electronic medical records containing vaccination data, microchip information, certificates, and health history. (4) Push notifications with reminders for appointments, vaccinations, and preventive care. (5) An integrated payment system for service fees. (6) Access to clinic reviews and ratings. (7) Separate profiles for each pet.

The development of any software product, including mobile applications, begins with building a conceptual model, which provides a generalized representation of the system's structure, its core components, the relationships between them, and their interaction with the external environment. The conceptual model is a critical part of the design stage, as it enables a comprehensive vision of the system prior to the direct implementation of its functionality. The development of conceptual models for information systems in IT projects has been examined in studies [8–10].

The developed conceptual model of the "PetHealth" mobile application, designed to facilitate interaction between pet owners and veterinary clinics, is illustrated in Fig. 1. The system enables appointment scheduling, management of electronic medical records for pets, access to online consultations, and other activities related to pet care.

During the development of the conceptual model, a system analysis was conducted to define its structure, including the supersystem, subsystems, external connections, and functional components.

1. System: the "PetHealth" mobile application.
2. System analysis from a physical perspective. Supersystem: pet owners, veterinary clinics, payment systems.

Subsystems include: (1) Mobile application (the main subsystem for appointment scheduling, clinic search, interaction with veterinarians, and receiving medical recommendations). (2) Pet owners (individuals who register their pets, search for veterinary clinics, and book appointments). (3) Veterinary clinics (entities that manage appointments, maintain pets' medical records, and provide consultations). (4) Administrative panel (a specialized subsystem for system administrators, enabling user management, content control, monitoring of the system's technical status, and configuration of general service settings). Table 1 provides a detailed breakdown of the elements that comprise each subsystem.

Table 1

Detailed breakdown of subsystem components

Subsystem name	Subsystem component
Mobile application	User interface; online appointment scheduling system; pet medical records; online consultation module with veterinarians; search function for doctors and veterinary clinics; service payment feature
Pet owners	Pet registration; medical record viewing; creation and management of online appointments; account settings
Veterinary clinics	Appointment management system; pet medical record maintenance; user interaction module; management interface
Administrative panel	User management; content management; system monitoring; settings management

3. Definition of the system's external connections with the supersystem. External influencing factors: (1) Pet owners (schedule online appointments with veterinarians, ask questions, and receive consultations through the app). (2) Veterinary clinics (accept online appointments and maintain records of pets).

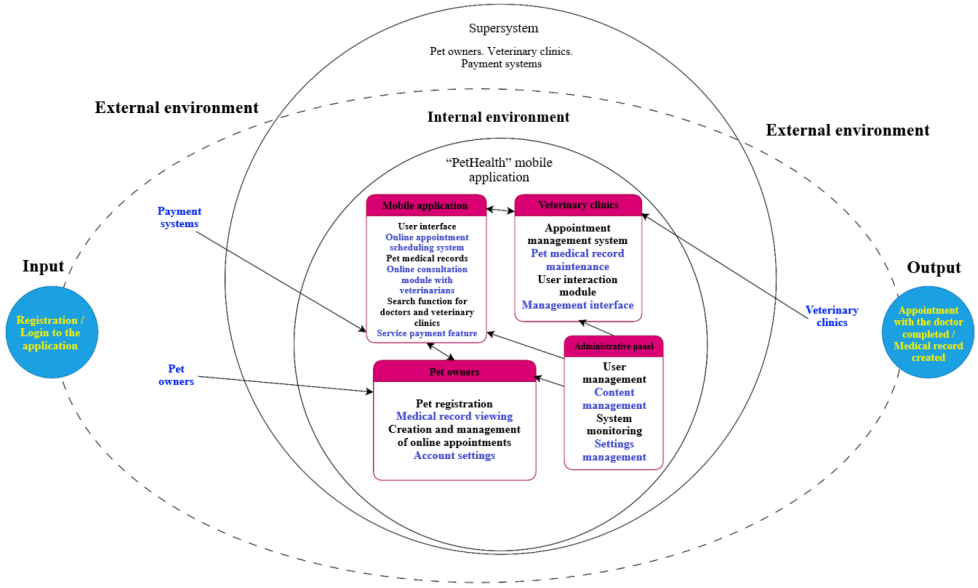

Fig. 1. Conceptual model of the "PetHealth" mobile application

The "PetHealth" system consists of key elements represented assets that describe the main objects and their roles within the mobile application. Each set corresponds to a specific category of data processed by the system.

Key sets:

1. Set of registered mobile application users:

$$U = \{u_1, u_2, \ldots, u_i\}, \tag{1}$$

where u_i – an individual app user who has a personal account.

2. Set of pets registered in the system:

$$P = \{p_1, p_2, \ldots, p_j\}, \quad (2)$$

where p_j – a uniquely registered pet associated with a specific user.

3. Set of veterinary clinics:

$$C = \{c_1, c_2, \ldots, c_k\}, \quad (3)$$

where c_k – a specific clinic with its own address, operating hours, and veterinarians.

4. Set of veterinarians:

$$V = \{v_1, v_2, \ldots, v_m\}, \quad (4)$$

where v_m – an individual veterinarian who provides consultations and conducts appointments.

5. Set of appointment records:

$$A = \{a_1, a_2, \ldots, a_t\}, \quad (5)$$

where $a_i = (u_i, p_j, c_k, v_m, t)$ – an appointment record of user u_i booking a visit with pet p_j to veterinarian v_m at clinic c_k at time t.

6. Set of medical records for each pet:

$$M = \{m_1, m_2, \ldots, m_z\}, \quad (6)$$

where m_z – the medical history of an individual pet, compiled from appointment outcomes and test results.

7. Set of online consultations:

$$O = \{o_1, o_2, \ldots, o_q\}, \quad (7)$$

where $o_i = (u_i, m_j, t, d)$ – a consultation between user u_i, and the veterinarian reviewing medical record m_j at time t; d – description of the consultation content.

8. Set of payments for veterinary services rendered:

$$S = \{s_1, s_2, \ldots, s_r\}, \quad (8)$$

where s_r – a specific transaction corresponding to an appointment booking or other clinic service.

9. Set of users with administrator privileges:

$$Adm = \{adm_1, adm_2, \ldots, adm_h\}, \quad (9)$$

where adm_h – the number of administrators in the system.

The system's elements are interconnected by relationships that define their interactions and the application's operational logic. These connections ensure the system's integrity and functionality.

1. The relationship between a user and pets is such that each user $u_i \in U$ can have one or more pets $p_j \in P$, associated with their account:

$$u_i \rightarrow p_j. \quad (10)$$

2. The relationship between a veterinarian and a clinic is defined such that each veterinarian $v_m \in V$ works at a specific clinic $c_k \in C$:

$$v_m \rightarrow c_k. \quad (11)$$

3. The appointment booking relationship is a complex association that links several entities simultaneously: the user, the pet, the clinic, and the veterinarian. An appointment booking is described as:

$$a_i = (u_i, p_j, c_k, v_m, t), \tag{12}$$

where t – the point in time for which the appointment is scheduled.

4. The relationship between a pet and its medical record describes the correspondence of each pet $p_j \in P$ to a single medical record $m_j \in M$:

$$p_j \to m_j. \tag{13}$$

5. The online consultation relationship reflects the interaction between the user and the veterinarian who has access to the medical data:

$$o_i = (u_i, m_j, t, d), \tag{14}$$

where d – consultation data.

The system performs a set of key functions that provide its core functionality. These functions are represented as mathematical operations describing the actions of users, veterinarians, and administrators.

6. User registration.

The user registration function f_{reg} takes the user's personal data d as input and adds a new user u_i to the set U:

$$f_{reg}(u_i, d) \to u_i \in U, \tag{15}$$

where d – user data: first name, last name, email, phone number.

7. Adding a pet.

The function f_{pet} facilitates the registration of a pet p_j belonging to user u_i based on the parameters d_p:

$$f_{pet}(u_i, p_j, d_p) \to p_j \in P, \tag{16}$$

where d_p – pet data: name, species, breed, date of birth, gender.

8. Appointment booking.

The function f_{app} creates an appointment record a_i for a veterinary visit:

$$f_{app}(u_i, p_j, c_k, v_m, t) \to a_i \in A, \tag{17}$$

where t – the user-selected appointment time.

9. Online consultation.

The function f_{cons} initiates an online consultation between the user and the veterinarian:

$$f_{cons}(u_i, v_m, t, d) \to o_i \in O, \tag{18}$$

where d – data transmitted during the consultation.

10. Service payment.

The function f_{serv} processes payment for a clinic appointment:

$$f_{serv}(u_i, c_k, a_i, sum) \to s_i \in S, \tag{19}$$

where sum – the payment amount associated with the appointment a_i.

11. Administrative panel.

The function f_{admin} performs administrative actions on system objects (such as users, clinics, appointments, etc.) on behalf of the administrator adm_i:

$$f_{admin}(adm_i, X) \to action, \tag{20}$$

where $adm_i \in Adm$ – an administrator with the appropriate access rights;

$X \in \{U, C, V, A, M, O, S\}$ – a set of objects: users, clinics, veterinarians, appointments, medical records, consultations, payments;

action – one of the administrative actions: *update*, *delete*, *monitor*.

To ensure data integrity, prevent conflicts, and maintain the business logic of the "PetHealth" system, the following logical constraints are imposed:

12. Avoiding overlapping appointments for the same veterinarian.

A veterinarian cannot have more than one appointment at the same time:

$$a_i = (u_1, p_1, c_1, v_m, t) \Rightarrow \nexists a_j \neq a_i : a_j = (u_2, p_2, c_2, v_m, t). \quad (21)$$

His ensures the uniqueness of time slots in the veterinarian's schedule $v_m \in V$.

13. Access to the medical record.

Viewing the medical record $m_j \in M$ is permitted only to the registered pet owner $u_i \in U$ or the veterinarian $v_m \in V$, who is responsible for the pet:

$$access(m_j) \in \{u_i, v_m\}. \quad (22)$$

14. Payment condition.

Payment for the service can only be made after the appointment $a_i \in A$ has been confirmed by the clinic $c_k \in C$:

$$s_i \in S \Leftrightarrow confirmed(a_i, c_k) = true. \quad (23)$$

This representation not only enables a clear structuring of processes within the application but also provides a foundation for further analysis, optimization, and software implementation. The proposed model accounts for the key roles of users, veterinarians, and administrators, and allows for the definition of constraints necessary to ensure the correct and secure operation of the system.

Conclusions. In the course of this study, a conceptual and mathematical foundation was developed for the "PetHealth" information system project, designed to digitize and optimize veterinary service processes. Market analysis revealed a lack of comprehensive solutions capable of integrating clinic search, appointment scheduling, electronic medical record management, and online consultations into a single platform. The proposed conceptual model outlines the system's key subsystems (user, clinical, and administrative) and defines their interconnections, ensuring a structured and scalable software architecture.

Entity sets (users, pets, clinics, veterinarians, appointments, medical records, consultations, and transactions) were defined, along with mathematical functions governing their operations, which formalize the app's logic and establish algorithms for core business processes. A dedicated system of logical constraints was also developed to regulate data access, prevent scheduling conflicts among veterinarians, and ensure transaction accuracy.

The practical outcome of the research is the creation of a comprehensive theoretical model of "PetHealth", suitable for implementation as a cloud-based mobile application. It provides: (1) centralized storage of pet medical data; (2) a convenient appointment scheduling mechanism with geolocation filters and ratings; (3) automated reminders for preventive care; (4) online consultations and integrated payments; (4) streamlined interaction between pet owners and veterinary clinics.

The findings demonstrate that implementing "PetHealth" can significantly reduce administrative burdens on clinics, shorten appointment organization time, and improve the quality of veterinary care. Future research may focus on developing a prototype of the mobile application, testing it with real users, and integrating it with national pet registries to ensure compliance with European standards.

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