Extended Classification Model of Telemedicine Station

Roman Tsarov[1], Iryna Tymchenko[1], Vladyslav Kumysh, Kateryna Shulakova[2,1] and Liliia Bodnar[3]
[1]*State University of Intelligent Technologies and Telecommunications, Kuznechna Str. 1, Odesa, Ukraine*
[2]*Anhalt University of Applied Sciences, Bernburger Str. 57, Köthen, Germany*
[3]*South Ukrainian National Pedagogical University, Staroportofrankyvska Str. 26, Odesa, Ukraine*
c4r1980@gmail.com, mentalitett@gmail.com,vlad.kumish@gmail.com, katejojo29@gmail.com, bodnarl79@pdpu.edu.ua

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Abstract: In the paper the relevance of the scientific problem of creation and development of telemedicine networks and telemedicine stations was proved by a systematic analysis of modern scientific research and regulatory sources. The conducted analysis revealed that there is no unified and system approach in place helping to solve this problem, especially on designing stage and during the technical implementation of these networks and their points. It results in complete or partial incompatibility of existing designs, construction documentation and blueprints as well, which leads to difficulties with various fragments of telemedicine networks and impedes international cooperation in this field. In order to solve this problem the definition of the telemedicine station is given, also its subsystems composition is defined, and an extended telemedicine station classification model is developed in the paper. The proposed classification model is based on the faceted classification method. It allows constructing classes by using any combination of characteristic features of telemedicine stations, while omitting and not using some of the characteristic features. Within the framework of this classification, the intersection of individual classes of telemedicine stations is allowed. A mathematical description of the classification model in the form of a faceted formula is provided.

1 INTRODUCTION

The modern communications industry is characterized by the penetration of information and communication technologies (ICT) in all spheres of human activities. ICT tools have become a key of any industry system. One of the urgent tasks of modern society, is to increase the availability of medical services, as well as their quality [1]. The solution to this problem is the introduction of modern ICT into the health care system and the creation of telemedicine networks on their basis. The main task of the telemedicine network (TMN) is to solve the problems of health care in providing access to specialized and high-tech medical care to anyone, regardless of their location and social status.

TMN allows organizing innovative interaction of various healthcare institutions of different levels with specialized and multidisciplinary national-level healthcare centres using advanced ICT and the intellectual potential of the industry's leading specialists when providing skilled medical care to the population remotely. In regards to COVID 19 pandemic outbreak, aggravation of local military conflicts, war in Ukraine, powerful earthquakes in Turkey and Syria, the point of designing telemedicine centres and networks is more relevant than ever.

The field of telemedicine development is relevant and largely researched, as evidenced by the large number of works [1-9, 11-19]. Modern scientists pay attention to such aspects as:

- architecture and design of telemedicine networks and stations;
- organization of the information component of telemedicine;
- telemedicine implementation and development strategies taking into account national peculiarities;
- implementation of information services and systems for the organization of telemedicine services.

In [2] an approach of creating the telemedicine infrastructure in South Sudan is proposed. The crore of the mentioned approach points to the autonomous medical clinic on the basis of a transport module (container) called Clinic-In-ACan (CIAN), which is ready for use in any location. In [3], the authors proposed the design and specification strategy for using backbone optical communication lines as the wired terrestrial telecommunication component of the telemedicine network. Though [4] proposes a comprehensive approach to creating a network architecture for a nationwide telemedicine network that connects all regional hospitals and medical centres with the city hospitals and state hospitals. The approach considers the use of a web-based telemedicine system, which provides the basic services for medical teleconsultations. It is obvious that for the modern telemedicine networks and centres, the key network service is video conferencing. The peculiarities of organizing the telemedicine system based on videoconferencing are investigated in [5]. The proposed structure is based on a service-oriented architecture, taking into account the hierarchical relationships inherent in a medical organization. The authors of [6] investigate the use of cloud technologies and Grid-systems in the concept of telemedicine. Namely, they propose to use a computer network in a way of distributed sharing the Internet access to ensure the connection of remote telemedicine stations in rural areas. In [7] the issue of creating a telemedicine network based on a distributed peer-to-peer structure with all telemedicine stations as peers is investigated.

2 CURRENT STATE OF THE PROBLEM AND PAPER GOAL

The analysis of studies has shown that the need to create and to develop the telemedicine networks and telemedicine stations is undeniable, though there are a number of difficulties when implementing such projects, such as [1-8]:

- Lack of a unified regulatory framework governing the activities of telemedicine centers and the procedure for providing telemedicine services. This leads to inconsistency between the options for TMC construction and the requirements in standards, the characteristics of protocols adopted in medical diagnostics and MIS formats.
- Lack of unified approaches in development of technical designs when constructing and building TMNs. The requirements to TMN may be formed by several participants – the medical institution, the regulatory organization (ministry, health department), the project organization itself. It may cause the inconsistency and contradiction of these requirements.
- Incompatibility of designs used for different fragments of the telemedicine network.

In fact, it can be noted that research in telemedicine is not systematic - some tasks and problems are given considerable attention, while others, on the contrary, are little elaborated. All this has led to the fact that today mostly there are no unified approaches and system solutions for developing and creating the technical projects and designs of telemedicine networks and stations. Mostly to this moment telemedicine networks and stations were created separately, without coordination and planning for further integration with other similar networks and stations. As a result a significant number of the implemented projects are incompatible with each other, which in turn affects the development of national telemedicine networks.

As already mentioned, the construction of telemedicine networks and stations is an urgent scientific problem, but the lack of unified and systematic approach towards its solution has led to significant confusion, starting even with the terminology. This causes certain problems during the creation and implementation of international projects and initiatives in the field of telemedicine. For example, the term telemedicine itself has more than 100 different definitions [1, 8, 12-16].

The purpose of this work is to provide a basic definition of the term telemedicine station as the ground element of a telemedicine network and to develop a classification model of telemedicine stations. This classification model is called to become a foundation in order to create standard, unified technical and design solutions for constructing the telemedicine stations and networks.

3 TELEMEDICINE STATION CLASSIFICATION MODEL

In [11] it is stated that telemedicine station and telemedicine center are the basic objects of telemedicine network (Figure 1).

These two terms are fairly widely used. The term telemedicine center is more formalized, although different sources provide somewhat different definitions for this term. For example, [14] defines such concepts as a telemedicine consultation center and a specialized telemedicine center, [12, 13] defines the term telemedicine center, and [15] defines such a concept as a telemedicine resource center. On the other hand, the term telemedicine station is not as formalized: it is widely used in various studies [10, 17, 18], but there is no official definition of this term. With this in mind, the following definition of the term is proposed:

Telemedicine station (TS) is an element of the telemedicine network that enables the clinical tasks handling, equipped with all the necessary facilities to provide and deliver the telemedicine services at the station.

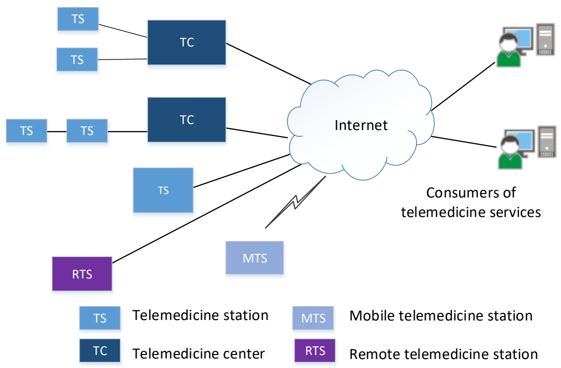

Figure 1: A generalized diagram of telemedicine network organization.

It follows from the proposed definition that telemedicine station should contain the following subsystems, namely:

A) Basic subsystems:

1) Telemedicine (information) subsystem.
2) Medical device subsystem.
3) Telecommunications subsystem.
4) Power supply and electric lighting subsystem.

B) Specialized subsystems:

1) Engineering subsystems (ventilation, water supply, sewerage, air conditioning, heating, etc.).
2) Security subsystems (access control, video surveillance, emergency and fire warning, etc.).
3) Transportation subsystem.

Telemedicine (information) TS subsystem includes hardware and software for automation of workflow and diagnosis, remote examinations, video consultations and videoconferences. Technically these achieved through the collection, input/output, digital processing, intelligent analysis, visualization, classification, storage, archiving, transfer to various media, transmission and provision of medical data and background information on request.

TS medical devices subsystem includes a set of instruments, devices, accessories, equipment, materials and other products used for medical purposes, whose functional purpose is not realized by pharmacological, immunological, genetic or metabolic effects on the human body. Medical devices can be used separately or in combination, as well as together with other accessories necessary for the intended use of these products, including special software.

Telecommunication subsystem of the TS is intended for connecting the medical devices (which have network interfaces) to the TS telemedicine information subsystem, as well as connecting TS itself to telemedicine centers, specialized stationary medical institutions or to external data transmission network (e.g., Internet). Telecommunication subsystem includes hardware and software, as well as communication lines.

Obviously, depending on the clinical tasks the telemedicine station will perform, the services it will provide, and on the external conditions - its characteristics and structure of its subsystems may vary. So, telemedicine stations can be classified in the space of their features, and in general, the entire set of telemedicine stations can be described on the basis of a classification model. Obviously, in this case, there will be no rigid classification structure, because the same telemedicine station may have functional characteristics that correspond to different classes. Moreover, a finite number of classes in the classification system cannot be clearly defined in advance since the new classes may appear in the process of analyzing the characteristics of different TS. With that said, we propose to create the TS classification model based on faceted classification technique [10].

The faceted classification technique enables the creation of a classification system from many independent subsets – facets. Each facet Φ_i contains a number of values taken by this feature or criteria. These values are mutually excluded.

In general, the classification system can be described by the following faceted formula

$$ClS = (\Phi_1, \Phi_2, ..., \Phi_n).$$

Let's consider some set of telemedicine stations - *PT*, over which the U_{PT} set of stations' features is defined:

$$U_{PT} = \{u_{PTi} \mid i = 1, ...k\},$$

here u_{PTi} stand for the elements of U_{PT} set.

Then the facetted set *ClS* can be defined over the *U* set as following:

$$ClS(U) = \{ClS_k \mid k = 1,...t\},$$

here ClS_k denotes the facet, which defines the k^{th} classification feature of the telemedicine station.

Each facet can take the defined set of possible values:

$$\phi^{ClS_k} = \{\phi_{k1},...\phi_{km}\},$$

here *m* denotes the number of possible values of i^{th} facet.

Each element of *PT* set should contain at least one value of the faceted feature:

$$\phi_j(u_{PTi}) = \{\phi_{ks}(u_{PTp}),\ p \in \{1,...k\}\} \subset \phi^{ClS_k}.$$

The set containing all the facetted features can be defined as following:

$$\phi_j(u_{PTi}) = \{\phi_{ks}(u_{PTp}), \forall p : p \in \{1,...k\}, \phi_j(u_{PTi}) \neq \varnothing\}.$$

The overall faceted formula *Ff* to classify the telemedicine station is following:

$$Ff\ (u_{PTi}) = \left\{ \begin{matrix} [ClS_j : \phi_j(u_{PTi})] \mid ClS_j \in ClS(U), \\ \phi_j(u_{PTi}) \in \phi^{FS_k} \forall j \in \{1,...,k\}, \phi_j(u_{PTi}) \neq \varnothing \end{matrix} \right\}. \quad (6)$$

In [18], the following criteria are proposed as classification features (facets):

1) Type of communication TS (connection) with the telemedicine network.
2) Type of energy and power supply organization in TS.
3) Type of provided telemedicine service in TS.
4) Distance to the central or regional nodes of the telemedicine hub.
5) Type of placement.
6) Type of construction.
7) Type of ownership.
8) Subordination level.
9) Degree of mobility.

Further research allows to supplement this list with the following criteria, namely:

- Type of telemedicine services provision mode.
- Type of access mode.
- Integrity level.

Taking into account additional classification criteria and, grounding on the basic classification model of telemedicine stations [18], the following extended classification model can be formed (Table 1).

Table 1: Telemedicine station extended classification model.

Facet (feature/criteria)	Faceted value
Type of connection to TMN	Wired connection
	Wireless connection
Degree of mobility	Stationary
	Portable
	Mobile
Type of telemedicine service provided	Basic (only one type of telemedicine service is provided)
	Diagnostic (several types of diagnostic telemedicine services are provided)
	Universal (any telemedicine services provided)
Type of energy and power supply	"Green" (station is powered using the renewable sources e.g. solar energy)
	Hybrid (power supply designed by the classic scheme, and the backup using the renewable sources)
Distance to the central or regional telemedicine hub	Local
	Outlying
Type of placement	Station of walking accessibility (located in places of mass gathering of people e.g. airports, business centers, etc.)
	Establishment station (located on the territory of some medical institution)
	Separate station (separate institution with all the necessary infrastructure)
Type of construction	Open station
	Cabin
	Cabinet
Subordination level	National
	Oblast/Regional
	Urban
	District
Type of ownership	State
	Municipal
	Private
Type of telemedicine services provision mode	Station of provision of services in automatic mode (monitoring)
	Station of provision of services on demand
Type of access mode	Personal station
	Stations of common use
Integrity level	Distributed station
	Non-distributed station

A clear interaction between all participants of the TS design process can be achieved only if all parties have the same understanding of TS characteristics, which is impossible without the initial TS classification. After implementing the classification system the further success of the design stage depends on the development of the unified approaches to solving 2 interrelated tasks:

- initial selection of the optimal option to implement a given class of TS;
- subsequent standard design at all stages of the technological process of building and deploying TS infrastructure.

To determine the class of TP based on the proposed model, it is necessary to get answers to some of questions regarding the structure of TP and related factors. This process can be formalized in the form of an algorithm, which is a further step of the research.

4 CONCLUSION

In this paper we define the telemedicine station term, determine the composition of its subsystems, and develop an telemedicine station extended classification. The advantage of the given classification model is the possibility of almost unlimited addition of the number of telemedicine station features and the use of already created classifiers as facets, which allows adding new classes to the model and developing the model. The proposed classification model allows one to determine the class of telemedicine station quickly, which will greatly simplify the task of telemedicine station design and will reduce the time-range required to develop the necessary design documentation.

It is obvious that the proposed classification model is not exhaustive and can be further supplemented and modified. Further research should be aimed at obtaining standard design solutions for constructing the telemedicine stations and networks in conditions of different types of input data.

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