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# Cyber security risks in telepresence robotics and their mitigation

Master's Thesis (21 ECTS)

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# **Cyber security risks in telepresence robotics and their mitigation**

## **Abstract:**

Telepresence robotics (TRPs) have become increasingly popular, particularly in higher education systems, as they enable users to remotely partake in events. However, this increased usage also presents potential security risks specific to TRPs, such as remote connections, cyber-physical presence, and live video and audio feeds. Current risk assessment models do not adequately address these unique concerns, leading to a gap in understanding and mitigating TRPs related risks. This thesis aims to map potential security issues, offer mitigation strategies for found weaknesses, and bridges the gap by conducting case studies and expert interviews. This research will provide organizations utilizing TRPs with a better understanding of security risks and effective solutions to protect their systems and users.

**Keywords:** Cyber security, risk assessment, telepresence robotics

**CERCS:** T120 System technology, computer technology

# **Küberturvalisuse riskid kaugosalus robotikas ja nende vähendamine**

## **Lühikokkuvõte:**

Kaugosalus robotid on muutunud üha populaarsemaks, eriti kõrgemas haridussüsteemis, kuna need võimaldavad kasutajatel osaleda üritustel kaugjuhtimise teel. Siiski kaasnevad selle suurenenud kasutamisega ka kaugosalus robotitele omased potentsiaalsed turvariskid, nagu kaugühendus, küber-füüsiline kohalolek ning reaajas video- ja heliside. Praegused riskihindamise mudelid ei käsitle piisavalt neid ainulaadseid probleeme, ning on olemas lünk seotud riskide mõistmisel ja nende leevendamisel. Käesoleva magistritöö eesmärk on kaardistada potentsiaalsed turvaprobleemid ja pakkuda leitud nõrkuste leevendamiseks strateegiaid ning ületada lünk, viies läbi juhtumiuuringuid ja ekspert intervjuusid. See uurimus annab kaugosalus roboteid kasutavatele organisatsioonidele parema arusaama turvariskidest ja tõhusatest lahendustest nende süsteemide ja kasutajate kaitsmiseks.

**Keywords:** Küberturvalisus, riskianalüüs, kaugosalus robotika

**CERCS:** T120 Süsteemitehnoloogia, arvutitehnoloogia

## **List of Abbreviations and Terms**

**CRD** Center for Reviews and Dissemination

**TRPs** Telepresence robotics

**UI** User interface

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# 1 Introduction

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## 1.1 Problem Statement

With the increasing popularity of TRPs in higher education systems, enabling users to remotely partake in events, new security risks specific to TRPs have emerged. These risks include remote connection, cyber-physical presence, and live video and audio feed vulnerabilities. However, current risk assessment models do not adequately address these unique concerns, resulting in a knowledge gap in understanding and mitigating TPR-related risks. This master's thesis aims to explore potential security issues associated with TRPs and propose methods to mitigate them by reviewing the state of art, conducting case studies and interviewing experts.

The research will involve identifying and validating potential risks through case studies and expert interviews, with a focus on user data security. By proposing mitigation strategies and emphasizing user data security, this study seeks to provide organizations utilizing TRPs with a better understanding of security risks and effective solutions to protect their systems and users. Ultimately, this research will contribute to bridging the gap between existing risk assessment models and the unique security concerns presented by the growing use of TRPs in higher education systems.

## 1.2 Objectives and Roadmap

### 1.2.1 Research Objective

The primary objective of this thesis is to identify cybersecurity risks related to organizations using TRPs and propose mitigation strategies to reduce the identified risks, focusing on user data security.

### 1.2.2 Research Questions

**RQ: To what kind of security risks are organisations using TRPs exposed to, and how to mitigate the risks?**

The main research question is divided into three different how questions, the potential security risks posed by TRPs, how organisations have assessed the potential risks and the solutions that can be provided to reduce the identified risks. The following sub-research questions are formulated in sequential order according to their importance:

1. **RQ1:** What are the potential security risks posed by TRPs, and how do these risks uniquely impact organizations utilizing these systems?

2. **RQ2:** How have organizations implemented assessment and management strategies to address cybersecurity risks associated with telepresence robotics?
3. **RQ3:** What potential solutions can be provided to reduce identified security risks?

**RQ1:** Identification of potential security risks posed by TRPs is the first step. In this step the possible security risks will be identified by analyzing existing frameworks, mitigation strategies and previous works in the field. This sub-research question focuses on uncovering the distinct security risks associated with telepresence robotics and examines their implications for organizations that deploy TRPs. By identifying these risks, the research will contribute to a comprehensive understanding of the challenges and vulnerabilities that need to be addressed in order ensure secure operation of TRPs systems. This exploration will consider various aspects of TRPs, such as remote connectivity, cyber-physical presence, and live video and audio feeds, to highlight the unique security concerns that arise from their use. Additionally, the research will investigate how these risks may differ from those faced by organizations using other types of robotics and what factors contribute to the increased vulnerability of TRPs systems.

**RQ2:** Once we have identified possible security risks the next step is to examine how have organizations implemented assessment and management strategies to address cybersecurity risks associated with TRPs? This sub-research question focuses on understanding the mechanisms and processes involved in managing TRPs systems. Finding the issues and gaps in current implementation is important to validate found security risks from teoretical material, but is also important before appropriate mitigation strategies can be considered. Addressing this question is essential for identifying potential vulnerabilities and areas where security improvements can be made.

**RQ3:** Following the identification of security risks associated with TRPs, this sub-research question concentrates on investigating and proposing potential mitigation strategies that effectively address the recognized risks. The study will explore a range of solutions, including technological advancements, policy implementation, and organizational practices, to provide a comprehensive understanding of how organizations can secure their TRPs systems. The proposed solutions should be practical, effective to the needs of organizations using TRPs. This will involve considering the unique security risks posed by TRPs and the distinct contexts in which they are deployed. The focus will be on user data security and the interaction between external users and TRPs, ensuring that the proposed mitigation strategies safeguard sensitive information and maintain the privacy and security of all parties involved.

By addressing these three sub-research questions, the thesis aims to provide a comprehensive understanding of the security risks faced by organizations using TRPs and offer practical solutions for mitigating these risks, ultimately contributing to a more secure and reliable TRPs environment.

### **1.2.3 Roadmap and Structure**

To achieve the research objective, the following roadmap and structure will be followed:

1. Literature Review and analysis: A comprehensive review of existing research on TRPs, risk assessment models, and related frameworks will be conducted to identify potential issues within TRPs systems.
2. Case Studies: Case studies will be conducted to validate existence of possible security risks by analyzing real-life scenarios involving TRPs usage in organizations;
3. Expert Interviews: Interviews with technical staff who have experience in integrating TRPs into organizations will be conducted to confirm the identified risks and explore possible mitigation strategies proposed by the experts;
4. Data Analysis and Proposed Mitigation Strategies: The findings from case studies and expert interviews will be analyzed to identify potential security concerns and risks posed by TRPs, as well as potential solutions to these risks;
5. Conclusion: The thesis will conclude by summarizing the key findings, discussing the limitations of the research, and suggesting avenues for future research.

Following this roadmap, the thesis will contribute to bridging the gap between existing cybersecurity knowledge regarding robotics in higher education systems and the unique security concerns presented by the growing use of TRPs.

## **1.3 Preliminaries**

None?



## **2 Background / State of the Art**

### **2.1 Telepresence Robotics**

### **2.2 Cyber Security Risks in Robotics**

### **2.3 Existing Risk Assessment Models**

### **3 Data Analysis**

#### **3.1 Identified Security Risks in TPRs**

#### **3.2 Existing risk assessment and management strategies**

#### **3.3 Proposed Mitigation Strategies**

## **4 Case Study: TalTech IT College (ICO)**

### **4.1 Context and TRPs Deployment**

### **4.2 Results and Findings**

### **4.3 Recommendations**

## **5 Expert Interviews**

### **5.1 Participant Selection**

### **5.2 Interview Results**

### **5.3 Expert Validation and Proposed Solutions**

## 6 Contribution

### 6.1 Research method

Primarily focus is on exploring and understanding the underlying perspectives, and experiences of the participants involved where TRPs have been deployed. Given the nature of the study, the absence of known empirical data, and the limited time for conducting case studies, a qualitative research approach will help to gain deeper insights. Thus it is important to develop a review protocol which sets the framework for conducting a thorough and unbiased review of the literature. It ensures that systematic and rigorous approach is followed, which enhances the credibility and reliability of the review. Following review protocol helps to minimize the risk of bias in the review process by establishing predefined criteria for study selection, quality assessment, and data extraction.

1. Establish the background and context of the study;
2. Formulate clear and specific research questions;
3. Define the search strategy, including search terms and resources to be used;
4. Set the study selection criteria and procedures;
5. Develop study quality assessment checklists and procedures;
6. Design a data extraction strategy tailored to the research questions;
7. Plan the synthesis of the extracted data, including descriptive and quantitative methods, as appropriate;
8. Outline a dissemination strategy for the review findings;
9. Set a project timetable to ensure timely completion of the review [1, pp. 4–5].

### 6.2 Search strategy

Search strategy was developed to identify relevant literature for this review following the search strategy generation guidelines [1, pp. 7–8]. Search strategy for the following thesis consists of 3 steps:

1. Generation of keywords and search terms;
2. The use of search filters;
3. Selection of credible sources.

**Keywords:** Initially, the search keywords were created by breaking down the research questions into their main concepts. A list of search terms and phrases related to each

key concept was generated by applying term harvesting to each research question. Main keywords were complemented by synonyms, alternative spellings, acronyms, and related terms to ensure a comprehensive search. The result was a list of search terms and phrases used to query the databases. To narrow down the search, the terms were combined using Boolean operators (where applicable).

Table 1. Selected keywords and synonyms

	Primary keywords	Secondary keywords (synonyms)
1	telepresence	telerobotics
2	robotics	robot
3	cybersecurity	cyber, security
4	risks	compromise, assessment, management
5	organization	organizations

**Filters:** The search filters were used to limit the search to the relevant studies. Most common filters used were: publication year, type of publication and language. The filters were applied to the search results to ensure that only relevant studies were included in the review. Most important filter being the publication year. The search was limited to the last 10 years (2013-2023) to ensure that only the most recent and relevant studies were included in the review. Primary studies were limited to maximum age of 5 years and secondary studies to maximum age of 10 years. Search filters of primary studies complemented the secondary search filters.

Table 2. Used search filters

	Date	Type	Discipline	Language
Primary studies	BETWEEN 2023 AND 2018	Reports, Journals, Experiments, Datasets	Computer Science, Engineering	English
Secondary studies	BETWEEN 2023 AND 2013	Articles, Conference Proceedings, Whitepapers	Social Sciences, Psychology	Estonian

**Sources:** After conducting preliminary searches using chosen search terms, and filters in the selected resources, search queries were refined as needed to obtain required materials. Preliminary searches showed that using main keywords in search strategy produced large number of results but highly relevant studies, thus the use of secondary keywords was not optimal in search for primary studies. Record the search terms used and the number

of results obtained from each resource was recorded for later use to check for updates on the subject. Most filtering refinements were done in User interface (UI). To identify relevant research several databases were queried with the same search terms. Database selection was based on the main category of hosted works (technology), the number of publications published and the age of the portal. were:

Table 3. Selected sources in order of relevance

	<b>Publisher</b>	<b>Metrics</b>	<b>Year</b>	<b>Topics</b>
1	SpringerLink	1,200 journals	1996	Computer science, engineering, environment
2	IEEEExplore	5,360,654 articles	2000	Computer science, electrical engineering and electronics
3	Scopus	34,346 journals	2004	Life sciences, social sciences, physical sciences
4	ScienceDirect	15,000,000 articles	1997	Physical Sciences and Engineering, Life Sciences
5	Web of Science	200 million records	1998	Physical Sciences, Technology, Life Sciences & Biomedicine
6	LISTA	513 million records	2005	Automation, Classification, Electronic resources and ERM systems
7	Frontiers	185 academic journals	2007	Education, Computer Science, Robotics and AI
8	Google Scholar	389 million records	2004	Various topics

Default language selection was "English". Examples of search queries used with combination of search terms, filters on the selected resources:

1. SpringerLink – "telepresence OR robots OR cybersecurity OR education OR risks";
2. IEEEExplore – "("All Metadata":telepresence) OR ("All Metadata":robots) OR ("All Metadata":cybersecurity) OR ("All Metadata" :education) OR ("All Metadata":risks)";
3. Scopus – "TITLE-ABS-KEY ( telepresence OR robots OR cybersecurity OR education OR risks ) AND ( LIMIT-TO ( PUBYEAR , 2023 ) OR LIMIT-TO ( PUBYEAR , 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( SUBJAREA , "COMP" ) )".

Table 4. Number of articles found with primary search strategy in ascending order

<b>Publisher</b>	<b>Date</b>	<b>Range</b>	<b>Type</b>	<b>Discipline</b>	<b>Number of studies</b>
SpringerLink	04.2023	2019-2023	Article	Engineering	57349
IEEEExplore	04.2023	2019-2023	Journals	Computer Science	61010
Scopus	04.2023	2019-2023	Article	Computer Science	101267
IEEEExplore	04.2023	2019-2023	All	X	221674
SpringerLink	04.2023	2019-2023	All	X	1649397
Scopus	04.2023	2019-2023	All	X	7865145

...

### 6.3 Selection of primary and secondary studies

To identify primary studies that provide direct evidence about the research question, specific selection criteria was defined during the protocol definition stage. Although criteria was refined during the search process, it served as a foundation for identifying relevant studies. The selection criteria included factors such as study design, levels of evidence, and outcome measures, ensuring that the chosen studies directly addressed our research question [1, pp. 10–16]. TRPs in the context of cybersecurity and education is a relatively new field of robotics in general with most research starting from 2015. Therefore, the selection of primary studies was extended to include secondary studies that provide indirect evidence about the research question. Primary studies were selected from search strategy results of which evidence level was at least 3. Secondary studies were selected from the from levels 4-5 based on Center for Reviews and Dissemination (CRD) hierarchy of evidence [1, p. 11]

### 6.4 Extracted data

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## **7 Validation**

### **7.1 Experimental validation**

## **8 Conclusion**

### **8.1 Summary**

### **8.2 Related work**

### **8.3 Implications for TRPs Users and Organizations**

### **8.4 Limitations and Future Research**

Time, resources, nr of case studies and access to experts are the main limitations of this research.

## References

- [1] Barbara Kitchenham. “Procedures for Performing Systematic Reviews”. In: *Keele, UK, Keele Univ.* 33 (Aug. 2004).

## **Appendix**

### **I. Data collected from case study**

## **II. Interview Guide and Consent Form**

### III. Licence

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