

Ontology for the prevention of digital crimes against children

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Abstract

The incidence of digital crimes against children has surged, with over half a million URLs featuring illicit content reported in 2023, predominantly targeting girls aged three to thirteen. This master's research project aims to develop an ontology that provides a semantic framework for information systems and applications grounded in international legal instruments, designed to assist governments, private sector organizations, and researchers in the prevention of digital crimes against children. The resulting ontology is based on the Basic Formal Ontology (BFO) and developed using the OntoForInfoScience methodology, encompassing nine stages from preparatory assessment to electronic availability. Early results from the completed stages have established the domain scope, user classes, application scenarios, and a foundational structure based on international legal instruments. The initial ontology includes core classes such as child, right, digital crime against children, and protection measures, each endowed with detailed properties and relationships, along with their respective information sources. This preliminary ontology structure encapsulates essential elements and interrelationships crucial for understanding and aiding in the prevention of digital crimes against children. Future work will involve completing the nine stages, formalizing the ontology using the Onto4All editor, and expanding it for broader application and international cooperation.

Keywords

ontology, child protection, digital crime against children, international legal instruments

1. Introduction

In the context of digital crimes against children (in this text, people under the age of eighteen years), in 2023 alone, over 540,000 URLs with potentially illegal and harmful content depicting the exploitation and sexual abuse of children were reported globally. Of this volume, girls represented nine out of ten children who were victims of child sexual abuse material. The age of 80% of the victims ranged from three to 13 years old [1].

Within this context, this research project is situated in the master's program in the Graduate Program in Information Management at the Federal University of Paraná, Brazil. This research project aligns with international efforts to prevent crimes against children, including digital ones. The aim is to create a domain ontology in English, with an international scope, based on international legal instruments, to assist governments, private sector organizations, and researchers in preventing digital crimes against children.

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As defined by the United Nations in the Convention on the Rights of the Child [2], a child is any human being under the age of eighteen years, except where the law applicable to the child provides otherwise and majority is attained earlier. According to the United Nations, violence against children is a complex and widespread phenomenon that affects all social classes and ages, compromising their physical, emotional, and intellectual development [3].

Considering this scenario, this research project aims to contribute to international efforts to protect children, particularly in the prevention of digital crimes. This will be achieved through the application of interdisciplinary scientific artifacts supported by Computer Science, Information Science, and Legal Studies. The chosen artifact is an ontology, whose creation and use enable the development of computational systems aimed at knowledge management, information retrieval, databases, and e-commerce [4]. Additionally, it serves to understand a domain by reducing it to models and creating controlled vocabulary, allowing inferences and information retrieval from documents in various formats and media [5].

Digital crime represents a paradigm shift in the landscape of criminal activities, characterized by the exploitation of digital technologies and virtual environments to perpetrate illicit acts. The advent and proliferation of digital technologies have fundamentally altered the nature of crime, transitioning many traditional offenses into the digital domain. Digital crime includes offenses such as fraud, identity theft, and cyberstalking, which are predominantly facilitated through digital means [6].

These crimes are predominantly executed within digital environments, taking advantage of inherent vulnerabilities in information and communication technologies. This technological shift has necessitated the adoption of terminologies like "cybercrime" and "computer crime", though "digital crime" serves as a more comprehensive term [7]. The distinctive characteristics of digital crime include the substantial geographical separation between perpetrators and victims, the anonymity that digital platforms afford to offenders, and the advanced technological methods employed in committing these offenses [6].

Regarding crimes against children, the vulnerability of this group is evident in the online environment, where they become targets for digital criminals. Studies highlight that the exposure of children to the Internet makes them more prone to becoming victims of digital crimes, such as online sexual abuse and cyberbullying [8]. Scientific literature emphasizes that violence against children, whether physical, psychological, or sexual, often begins in the domestic environment and can extend to the digital realm [9].

2. Similar Ontologies and Information Sources

For the development of this research project, similar ontologies, glossaries, and thesauri were sought in six databases: Protégé Ontology Library², Linked Open Vocabularies³, DataHub⁴, European Open Data Portal⁵, Ontobee⁶, and CEUR Workshop Proceedings⁷. Only one positive result was found: the Child-Safe ontology [10].

As described by its developers, the Child-Safe ontology "aggregates, organizes, and interrelates terminologies within the domain of preventing sexual crimes against children and adolescents". However, the ontology is still under development and, therefore, not yet accessible. Additionally, this ontology is being developed in Brazilian Portuguese, focusing exclusively on Brazilian

² https://protegewiki.stanford.edu/wiki/Protege_Ontology_Library

³ <https://lov.linkeddata.es/dataset/lov>

⁴ <https://datahubproject.io/>

⁵ <https://data.europa.eu/en>

⁶ <https://ontobee.org/>

⁷ <https://ceur-ws.org/>

legislation, and lacks international scope [10]. Consequently, the Child-Safe ontology will not be considered in this initial phase of the research.

The absence of precise representations, such as ontologies, for the topic of this research project increases the occurrence of improper use of terminology and, therefore, generates misinformation. This scenario can undermine initiatives to prevent digital crimes against children.

Thus, it is understood that the ontology designed in this research project is relevant to Computer Science, Information Science, and Legal Studies – and hence warrants investigation.

The initial information sources for the development of the first version of the ontology's semantic corpus include 16 international legal instruments (Appendix A) from international organizations representing groups of nations (Appendix B).

3. Structure and Methodology

The intended ontology, which is currently unnamed, will be developed based on the Basic Formal Ontology (BFO) [11], a foundational ontology, and will adhere to the OntoForInfoScience methodology [12, 13]. BFO is a top-level and foundational ontology renowned for its rigor, widespread adoption, and capacity to provide a universal framework for categorizing entities across diverse domains. Aligning the domain ontology with BFO ensures a robust, coherent, and logically consistent structure that facilitates interoperability across various systems [11]. This strategic alignment not only enhances the ontology's scalability and adaptability by future researchers, but also ensures compatibility with other BFO-aligned ontologies. Such compatibility fosters collaboration and supports the ongoing development and evolution of the ontology, enabling it to adapt to emerging challenges in the prevention of digital crimes against children.

The OntoForInfoScience methodology was selected for the development of the ontology because of its thorough and well-defined approach to ontology creation, making it particularly suitable for those who are either new to the field or not experts in ontology. In the context of this research, OntoForInfoScience is essential as it addresses the intricate challenges associated with the interdisciplinary nature of digital crime prevention, enabling the construction of a logically consistent and well-structured ontology. By offering clear, step-by-step guidance, this methodology ensures that the ontology is theoretically sound and practically applicable, facilitating its effective use and future expansion by researchers and professionals across various fields [12]. Its flexibility and focus on formal representation are key to ensuring that the ontology functions as a standardized tool in the ongoing efforts to prevent digital crimes against children. Furthermore, a comparative analysis of existing methodologies – such as Methontology, 101 Method, and NeOn Methodology – reveals that many of these lack the detailed guidance needed for the development process, especially for non-experts [13]. OntoForInfoScience addresses these gaps by providing a more detailed and accessible framework, making it the most appropriate choice for this research context.

Developed in English with an international scope, the ontology will be made openly accessible through the Onto4All online ontology editor [14]. This ensures that researchers from various nations, who work on BFO-based ontologies and are committed to preventing digital crimes against children, will have the ability to access, expand, and refine it.

The documents pertaining to the ontology will be made available through a data management plan hosted on an openly accessible online platform of the Federal University of Paraná, in Brazil.

The OntoForInfoScience methodology [12] consists of nine stages:

1. Pre-stage (Stage 0): Preliminary assessment of the need to build an ontology for the analyzed problem.
2. Stage 1: Specification of the ontology through a template that includes domain and scope, general purpose, user classes, application scenarios, and degree of formality.

3. Stage 2: Knowledge acquisition and extraction, selecting reference materials and extraction methods.
4. Stage 3: Conceptualization, identifying and analyzing domain concepts to be included as ontology classes.
5. Stage 4: Grounding, researching and selecting foundational ontologies appropriate for the goal.
6. Stage 5: Formal representation of the ontology using a logical language.
7. Stage 6: Ontology evaluation through validation criteria (domain adequacy) and verification (construction correctness).
8. Stage 7: Formal documentation of the ontology, elaborated throughout the entire process.
9. Stage 8: Making the ontology available electronically, accessible to users.

4. Applications

The implementation of an ontology for the prevention of digital crimes against children offers substantial benefits. These applications encompass the development of specialized technologies and information systems, the formulation of public policies, and the enhancement of social awareness, thereby establishing it as a powerful and multifaceted tool.

These specific applications are detailed in Section 5 (Preliminary Results), within the Application Scenarios of Stage 1.

5. Preliminary Results

To date, Stages zero, one, and two of the OntoForInfoScience methodology [12, 13] have been completed, as detailed below.

5.1. Stage 0 (Preliminary Assessment)

As part of Stage 0, the need to build an ontology for the prevention of digital crimes against children reveals a significant gap in the current landscape of digital safety measures. Despite numerous international efforts and legal frameworks, the lack of a comprehensive, standardized ontology in this domain results in fragmented and inconsistent terminologies, hindering effective communication and coordination among stakeholders. The rising number of digital crimes against children, exacerbated by the anonymity and reach of the internet, underscores the urgent necessity for a structured ontology to unify and streamline preventative measures.

5.2. Stage 1 (Ontology Specification)

As part of Stage 1, the following elements need to be created: domain and scope, general purpose, user classes, application scenarios, type of ontology, degree of formality, and scope delimitation, as detailed below:

- **Domain and scope:** The ontology will encompass the domain of digital crimes against children, specifically focusing on online sexual exploitation, cyberbullying, identity theft, and exposure to harmful content. The scope will include terminologies, legal definitions, and procedural guidelines relevant to identifying, preventing, and responding to these crimes. The ontology will not cover broader categories of child abuse that occur offline unless they have direct digital counterparts.
- **General purpose:** The primary purpose of this ontology is to facilitate a unified framework that aids governments, private sector organizations, law enforcement, educators, and digital platform administrators in the prevention and mitigation of digital crimes against children.

By providing a standardized vocabulary and logical structure, the ontology aims to enhance the accuracy and efficiency of communication, reporting, and intervention strategies across international borders.

- User classes:
 - Developers and maintainers: Individuals responsible for the ongoing development, maintenance, and updates of the ontology.
 - Law enforcement and public authorities: Users who will employ the ontology for legal proceedings, crime prevention, and policy formulation.
 - Educators and trainers: Professionals utilizing the ontology to develop educational materials and training programs.
 - Digital platform administrators: Entities integrating the ontology into monitoring and reporting systems to enhance online safety.
 - Researchers and academics: Scholars conducting research on digital crimes and developing new methodologies for crime prevention.
- Application scenarios:
 - Development of monitoring tools: Creation of software and information systems ontology-based for monitoring to identify patterns of suspicious behavior and communications, as well as illegal online activities, facilitating the early detection of digital crimes against children.
 - Enhancement of reporting systems: Improvement of existing reporting systems by integrating a controlled and standardized vocabulary that facilitates communication between different organizations and nations, making the reporting process more efficient and accurate.
 - Training and capacity building: Development of training programs for security professionals and educators, using the ontology as a basis to educate about the risks and signs of digital crimes, as well as best practices for prevention and intervention.
 - Integration with online platforms: Implementation of algorithms based on the ontology to monitor, detect, and block harmful content and interactions involving children in chat and comment sections of online services and platforms, such as online games, and social media.
 - International cooperation: Utilizing a common language and set of concepts can facilitate cooperation between security agencies and justice systems across different nations, enabling a coordinated and effective response to digital crimes against children.
- Type of ontology: The developed ontology will be a domain-specific ontology with a medium level of formality. It will employ a structured yet flexible framework, balancing between rigorous formal definitions and practical usability to accommodate diverse user needs.
- Degree of formality: Given the ontology's purpose and user base, it will exhibit a medium degree of formality. This balance ensures that the ontology is sufficiently rigorous to support legal and technical applications while remaining accessible for educational and practical use. The ontology will use descriptive and logical properties to define classes, with a formal representation using a logical language suitable for integration into various systems.
- Scope delimitation:
 - Starting point: The ontology will begin with general classes derived from foundational ontologies like Basic Formal Ontology (BFO), supplemented with specific classes related to digital crimes against children.

- Domain limit: The ontology will represent knowledge up to the granularity level required for digital crime prevention, delegating deeper forensic and psychological aspects to specialized ontologies.
- Competency questions: The ontology will address critical questions such as:
 - How can digital crimes against children be categorized and identified?
 - What are the best practices for reporting and intervening in such crimes?
 - How can international cooperation be facilitated through standardized terminologies for preventing digital crimes?

5.3. Stage 2 (Knowledge Acquisition and Extraction)

As part of Stage 2, a preliminary ontology structure for the prevention of digital crimes against children has been developed based on a manual analysis and knowledge extraction from 16 international legal instruments (Appendix A). The preliminary ontology is depicted in a generalized format in Figure 1 and further elaborated in the subsequent paragraphs, for later inclusion in the Onto4All online ontology editor.

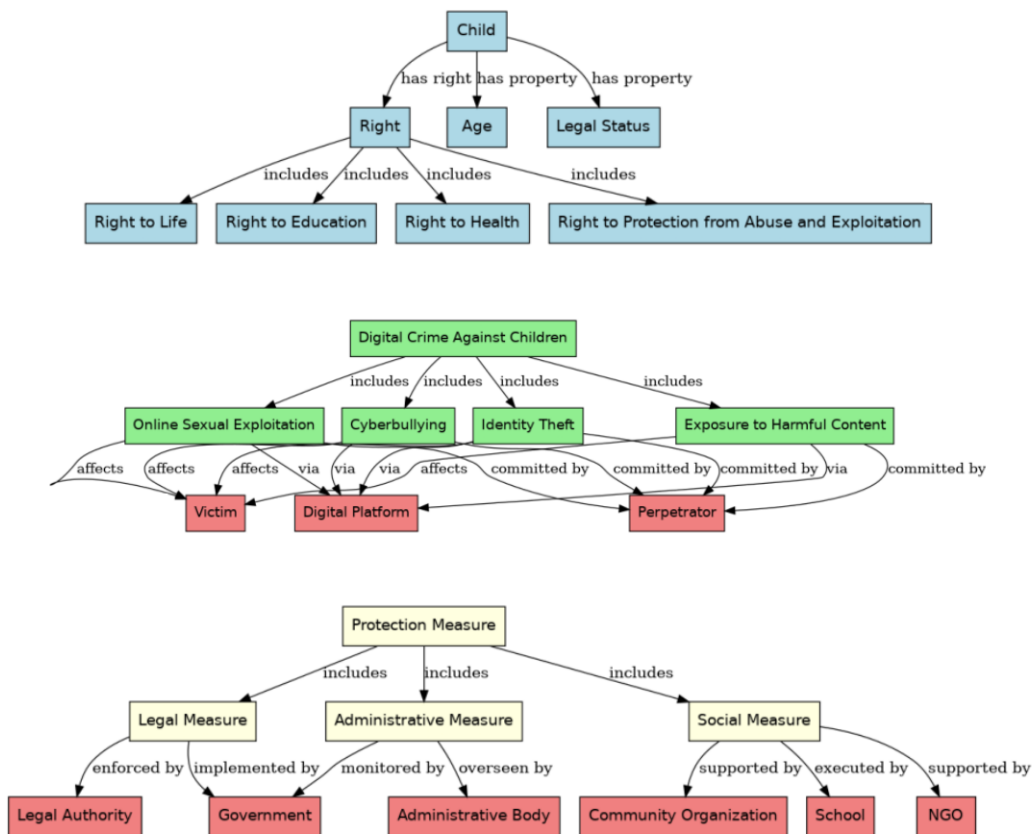


Figure 1: Diagram depicting the preliminary structure of the ontology. The three diagrams are complementary in nature, but in the current stage of the research, they are designed to be interpreted independently. Created by the authors.

The structure categorizes key terms and concepts into classes, subclasses, properties, and relationships, with their respective sources indicated in parentheses (showing their IDs from Appendix A), as follows:

- Core classes and definitions:

- Child: Defined as any human being below the age of eighteen years, unless under the law applicable to the child, majority is attained earlier (2).
 - Properties: age, legalStatus, right.
- Right: Fundamental entitlements of children as per international conventions and protocols (2).
 - Subclasses:
 - Right to life: The inherent right of every child to life, survival, and development (2).
 - Right to education: The right of the child to access education that develops their personality, talents, and mental and physical abilities to their fullest potential (2).
 - Right to health: The right of the child to enjoy the highest attainable standard of health and access to healthcare services (2).
 - Right to protection from abuse and exploitation: The right of the child to be protected from all forms of physical or mental violence, injury or abuse, neglect or negligent treatment, maltreatment, or exploitation, including sexual abuse (2).
- Digital crime against children: Illegal activity conducted through digital means targeting children (15, 6).
 - Subclasses:
 - Online sexual exploitation: The use of digital platforms to engage in the sexual exploitation of children, including grooming, distribution of child pornography, and online predation (6).
 - Cyberbullying: The use of electronic communication to bully a person, typically by sending messages of an intimidating or threatening nature (15).
 - Identity theft: The fraudulent acquisition and use of a child's personal information, often for financial gain (15).
 - Exposure to harmful content: The act of making harmful or inappropriate content accessible to children through digital means (15).
- Protection measure: Legislative, administrative, and social measure aimed at safeguarding children from digital crimes (2, 5, 15).
 - Subclasses:
 - Legal measure: Law and regulation designed to protect children from digital crimes and to prosecute offenders (5, 6).
 - Administrative measure: Policy and procedure implemented by governmental and non-governmental organization to monitor, report, and prevent digital crimes against children (15).
 - Social measure: Community-based initiative, awareness campaign, and educational program aimed at preventing digital crimes and supporting affected children (11, 9).
- Subclasses and properties:
 - Right:
 - Right to life:
 - Properties: inherentRight, protectionFromViolence, survivalAndDevelopment.

- Right to education:
 - Properties: accessToEducation, qualityOfEducation, educationalDevelopment.
 - Right to health:
 - Properties: highestAttainableStandard, healthService, accessToHealthcare.
 - Right to protection from abuse and exploitation:
 - Properties: legalProtection, socialProtection, psychologicalSupport.
- Digital crime against children:
 - Online sexual exploitation:
 - Properties: grooming, distributionOfChildPornography, onlinePredation.
 - Relationships: perpetrator, victim, digitalPlatform.
 - Cyberbullying:
 - Properties: harassment, onlineAbuse, onlineBullying.
 - Relationships: perpetrator, victim, digitalPlatform.
 - Identity theft:
 - Properties: dataBreach, fraudulentActivity, impersonation.
 - Relationships: perpetrator, victim, digitalPlatform.
 - Exposure to harmful content:
 - Properties: inappropriateContent, violentContent, explicitMaterial.
 - Relationships: perpetrator, digitalPlatform, victim.
- Protection Measure:
 - Legal Measure:
 - Properties: legislation, enforcement, prosecution.
 - Relationships: government, legalAuthority.
 - Administrative measure:
 - Properties: policy, monitoring, reporting.
 - Relationships: government, administrativeBody.
 - Social measure:
 - Properties: awarenessCampaign, educationalProgram, communitySupport.
 - Relationships: NGO, communityOrganization, school.
- Relationships
 - Perpetrator: The individual or entity committing digital crimes against children (6, 15).
 - Properties: identity, modusOperandi, criminalRecord.
 - Victim: The child subjected to digital crimes (2, 15).
 - Properties: identity, age, psychologicalImpact.
 - Digital platform: The online medium through which digital crimes are perpetrated (15).
 - Properties: platformName, securityMeasure, userBase.

- Government: The state authority responsible for implementing protection measures (2; 5).
 - Properties: jurisdiction, legislativeBody, enforcementAgency.
- Legal authority: Judicial and law enforcement entity involved in prosecuting digital crimes (5; 6).
 - Properties: police, judiciary, legalFramework.
- Administrative body: Governmental and non-governmental organization involved in administrative protection measures (15).
 - Properties: policy, monitoringMechanism, reportingSystem.
- NGO: Non-Governmental Organization working to protect children from digital crimes (11; 9).
 - Properties: advocacy, supportService, educationalInitiative.
- Community organization: Local group and institution supporting child protection measures (11).
 - Properties: communityProgram, supportNetwork, awarenessCampaign.
- School: Educational institution involved in social protection measures (9).
 - Properties: educationalProgram, studentSupport, safeguardingPolicy.

This comprehensive specification ensures that the intended ontology is robust, scalable, and aligned with international standards and practices, providing a powerful tool to assist in the prevention of digital crimes targeting children.

6. Discussion and Next Steps

This preliminary ontology structure captures the essential elements and relationships necessary to understand and help prevent digital crimes against children. It includes key classes such as child, right, digital crime against children, and protection measures, along with their respective definitions, information sources, subclasses and properties. The relationships between these classes help to illustrate the interconnected nature of the concepts, whose research is only four months in progress as of the publication of this paper.

The next steps involve transferring the preliminary ontology structure into the Onto4All online ontology editor. However, before proceeding, it is essential to complete Stage 2 (in Subsection 5.3) according to all the requirements of the OntoForInfoScience methodology, which includes using a computer-supervised method to extract knowledge from the information sources.

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A. International legal instruments on the rights of children from international organizations

ID	Year	International Legal Instruments (Organization)	Access
1	1985	The Beijing Rules (United Nations)	↗
2	1989	Convention on the Rights of the Child (United Nations)	↗
3	1993	Convention on Protection of Children and Co-operation in Respect of Intercountry Adoption (Hague Conference on Private International Law)	↗
4	1999	ILO Convention n. 182 on the Worst Forms of Child Labour (United Nations)	↗
5	2000	Protocol to Prevent, Suppress and Punish Trafficking in Persons Especially Women and Children, supplementing the United Nations Convention against Transnational Organized Crime (United Nations)	↗
6	2000	Optional Protocol to the Convention on the Rights of the Child on the sale of children, child prostitution and child pornography (United Nations)	↗
7	2000	Protocol Against the Smuggling of Migrants by Land, Sea and Air, supplementing the United Nations Convention Against Transnational Organized Crime (United Nations)	↗
8	2004	Optional Protocol to the Convention on the Rights of the Child on the Involvement of Children in Armed Conflict (United Nations)	↗
9	2005	ECOSOC Resolution 20/2005 - Guidelines on Justice in Matters involving Child Victims and Witnesses of Crime (United Nations)	↗
10	2007	International Convention on the Rights of Persons with Disabilities (United Nations)	↗
11	2009	Guidelines for the Alternative Care of Children (United Nations)	↗
12	2010	The Bangkok Rules (United Nations)	↗
13	2011	Optional Protocol to the Convention on the Rights of the Child on a Communications Procedure (United Nations)	↗
14	2015	The African Charter on the Rights and Welfare of the Child (African Union)	↗
15	2021	European Union Strategy on the Rights of the Child (European Union)	↗
16	2022	Recommendation on Children in the Digital Environment (OECD)	↗

B. International organizations used in the search for international legal instruments on the rights of children

ID	Member States	Internation Organization (Acronym)	Access
1	193	United Nations (UN)	➔
2	55	African Union (AU)	➔
3	54	The Commonwealth	➔
4	38	Organisation for Economic Co-operation and Development (OECD)	➔
5	35	Organization of American States (OAS)	➔
6	30	North Atlantic Treaty Organization (NATO)	➔
7	27	European Union (EU)	➔
8	22	League of Arab States (LAS)	➔
9	21	Asia-Pacific Economic Cooperation (APEC)	➔
10	18	Pacific Islands Forum (PIF)	➔
11	16	Southern African Development Community (SADC)	➔
12	15	Caribbean Community (CARICOM)	➔
13	10	Association of Southeast Asian Nations (ASEAN)	➔
14	9	Community of Portuguese Language Countries (CPLP)	➔
15	8	Shanghai Cooperation Organization (SCO)	➔
16	8	South Asian Association for Regional Cooperation (SAARC)	➔
17	8	Central American Integration System (SICA)	➔
18	6	Gulf Cooperation Council (GCC)	➔
19	5	Eurasian Economic Union (EAEU)	➔
20	4	Southern Common Market (MERCOSUR)	➔