Standardization and Classification of Icons on a Graphical User Interface for Visually Impaired Users

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Abstract

This study aims to establish a universal standard for software application icons, enhancing computer usability for visually impaired and elderly users. It addresses the challenges of graphical interfaces, such as the difficulty in distinguishing between similar icons or understanding complex iconography, and focuses on developing an intuitive, ontology-based classification system for software icons.

Utilizing Protégé for ontology construction, we systematically classified software function icons into tree structures. The methodology involved analyzing existing icon standards and applying the Toronto Visual Enterprise (TOVE) project methodology, which provided a structured approach to icon classification. Initially centered on Microsoft Word icons, the ontology was expanded to include a broader range of software functionalities.

Our method resulted in a user-friendly icon classification system with efficient search functions. Refined through a rigorous process of user feedback, especially from visually impaired individuals who provided insights on icon recognition and usability, the study established a comprehensive and standardized icon set, enhancing software usability.

The findings indicate that the ontology-based approach significantly improves computer usage for visually impaired users, offering new guidelines for accessible software design. This research contributes to creating more inclusive software interfaces and marks a notable advancement in accessible technology, inspiring further innovation in the field.

The study provides practical insights for software developers and designers in creating more accessible interfaces. The standardized icon set and classification system can be directly applied in software development, improving the usability for a diverse user base. This approach not only aids in complying with accessibility standards but also enhances the overall user experience, making software more intuitive and inclusive.

***Keywords*：** icon standard, computer use behavior, visually impaired, user interface

1. Introduction

Integrating technology into daily life has opened new avenues for accessibility, particularly for individuals with visual impairments. However, relying on graphical user interfaces (GUIs) poses significant challenges for these users. While technological advancements have made computers essential tools for communication and information access, the visual-centric design of most software applications creates a barrier for visually impaired and elderly users (Konecki, 2014).

The gap in software design for visually impaired users, especially in the context of icon usage in applications, is a critical concern. Standard computer interfaces, heavily reliant on visual cues, often prove inadequate for these users. This highlights the urgent need for a clear and universal standard for icon classification, which can significantly enhance usability and accessibility in software development (Chai & Cao, 2017).

This study aims to develop a universal standard for software application icons, improving computer usability for visually impaired and elderly users. Our focus is on creating comprehensible icons through text annotations and audio descriptions, addressing the limitations of braille displays, and catering to the specific needs of visually impaired and older users (Razaly et al., 2010).

The significance of this research lies in its potential to bridge the accessibility gap in computer technology. By standardizing icon design, we can facilitate a more inclusive digital environment, enabling visually impaired users to navigate software applications more effectively. This research not only contributes to the field of accessible technology but also provides valuable insights for software developers in creating more user-friendly interfaces (Gokhale et al., 2017; Palani et al., 2019).

2. Literature Review

2.1 Emerging Systems in GUI Design for the Visually Impaired

This section explores recent advancements in graphical user interface (GUI) design tailored explicitly for visually impaired users. The focus is on innovative systems and technologies that enhance accessibility and interaction for this demographic.

Konecki (2014) discusses the importance of including visually impaired users in the GUI design process, emphasizing the need for designs that cater to their unique requirements. Similarly, Chai and Cao (2017) explore barrier-free designs in GUIs, addressing the challenges visually impaired users face in accessing information.

In the realm of mobile applications, Gokhale et al. (2017) developed SparshJa, a user-centric mobile application designed to improve the quality of life for visually impaired users. This application demonstrates the potential of mobile technology to enhance accessibility. Palani et al. (2019) also studied touchscreen-based haptic information access, providing a novel way for visually impaired users to interact with GUIs.

Engel, Müller, and Weber (2019) introduced SVGPlott, an accessible tool for creating adaptable audio-tactile charts for visually impaired users. This tool represents an innovative approach to data representation, making information more accessible. Hirayama (2017) proposed a usability testing method for embedded systems, considering the needs of visually impaired users, which is crucial for developing inclusive technological products.

Lastly, the research by Konecki, Kudelić, and Gjoreski (2015) on GUIDL IA, an intelligent assistant for aiding visually impaired users in using the Graphical User Interface Description Language (GUIDL) system, highlights the potential of intelligent technologies in enhancing the interaction of visually impaired users with digital interfaces.

2.2 Ontology in Software Design for the Visually Impaired

Applying ontology principles in software design is pivotal in enhancing accessibility for visually impaired users. Traditionally associated with metaphysics, ontology has significant applications in artificial intelligence (AI) and information technology, particularly in structuring knowledge models. This section explores how ontology is integrated into software design to create intuitive and accessible iconography, especially for visually impaired users.

Recent advancements in AI and information technology have spurred the development of ontology languages for the web, including the Research Description Framework and Web Ontology Language. These developments, endorsed by organizations like the World Wide Web Consortium, have laid the foundation for our study's application of ontology in software design. By classifying objects' existence and attributes, we aim to redefine software iconography, making it more comprehensible and accessible, particularly for users dependent on assistive technologies.

Ontology, as defined by the World Wide Web Consortium, is instrumental in describing structured knowledge across various domains. It facilitates the sharing and interoperability of information among humans, databases, and software applications. Key ontology characteristics identified by scholars like Couldry and Kallinikos (2017) and Nasution (2008) include conceptualizing knowledge structures, formality, explicitness, and shareability. In our study, ontology is utilized in the hierarchical classification of software icons and symbols, employing a tree structure for systematic classification. This approach preserves domain-specific knowledge and enhances communication, interoperability, and systems engineering in software development.

2.3 Challenges for Visually Impaired Computer Users

Visually impaired individuals face unique challenges when using computers, which can significantly impact their daily lives and work efficiency. Essential features like voice-over and talk-back (Carvalho et al., 2018) are crucial for the usability of cell phones among visually impaired users. However, beyond these features, several other challenges persist.

One major challenge is the navigation of graphical user interfaces (GUIs) primarily designed for sighted users. The heavy reliance on visual cues in standard GUIs, such as icons and buttons, makes it difficult for visually impaired users to navigate software applications (Lazar et al., 2007). Identifying and selecting small icons or navigating through complex menus can be daunting without proper auditory or tactile feedback mechanisms.

Another significant challenge is the lack of standardization in assistive technologies. While screen readers and braille displays offer some relief, the inconsistency in their operation across different platforms and applications can lead to confusion and reduced productivity (Shinohara & Tenenberg, 2009). For example, a visually impaired user might be proficient in using a screen reader with a specific set of applications but may struggle when switching to a different software environment with a different set of commands and layouts.

The design of websites and digital content often lacks consideration for accessibility, leading to barriers to information access. Inaccessible websites, documents, and software can exclude visually impaired users from accessing vital information or participating in certain activities, impacting their educational and professional opportunities (Power, Freire, Petrie, & Swallow, 2012). Poorly labeled forms, non-descriptive link texts, and untagged website images can make online navigation and transactions frustrating and time-consuming for visually impaired users.

Furthermore, the emerging reliance on touchscreens poses additional difficulties. While touchscreens offer a sleek design and intuitive use for sighted users, they can be challenging for visually impaired users who rely on tactile cues (Rodriguez-Sanchez et al., 2014). The absence of physical buttons means that visually impaired users rely on trial and error or memorization to use these devices effectively.

In summary, these challenges highlight the need for inclusive design in computing technology that considers the diverse needs of all users, including those with visual impairments. Addressing these challenges is crucial for ensuring visually impaired individuals can participate fully in a digital world, enhancing their independence and quality of life.

2.4 Software for Visually Impaired Users

This section reviews three Windows-based software programs for visually impaired users in Taiwan: The Guide Mouse (G-Mouse) System and The Jaws System. Each program aims to improve the computing experience for visually impaired users through its unique features.

The Guide Mouse System, developed by the Resource Center for the Visually Impaired at Tamkang University, offers audio reading and internet browsing capabilities and is compatible with various braille displays. This system is favored for its user-fri

The Jaws System, created by International United/Assistive Technologies, is designed to overcome certain limitations of the G-Mouse and G-batol systems. It boasts many functionalities and shortcuts, making it a comprehensive tool for navigating complex software environments. The Jaws System is particularly suitable for professional or advanced users who require a feature-rich interface for their computing needs. For more information about the Jaws System, please refer to its official website or user manual.

In summary, these software systems significantly enhance computer accessibility for visually impaired users but face challenges in interpreting shape-based information. This limitation highlights the need for continuous innovation in software design better to meet the diverse needs of visually impaired users. Our study proposes developing a standardized set of icons for standard Windows software to simplify software development and improve accessibility, especially for users who rely on audio-controlled interfaces.

3. Research Methodology

3.1 Objectives, Data Collection, and Ontology-Based Classification

This study aims to develop a standardized set of computer icons and symbols to enhance usability for visually impaired individuals in Taiwan, addressing the challenges posed by graphical interfaces in modern systems. We collected icons from various Windows-based software interfaces and analyzed each for their design, functionality, and use context. Utilizing ontology principles, these icons were categorized into a structured hierarchy, facilitating a systematic understanding of their purposes and relationships. This process is illustrated in Figure 1, which depicts a tree-shaped structure representing the hierarchical organization of icons within categories such as 'Print.'

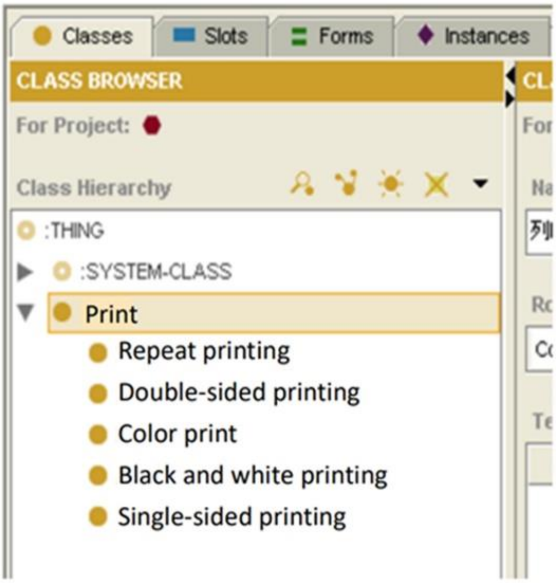

Figure 1. Print' example

3.2 Icon Standardization Process and User Testing

The standardization process involved redesigning the icons for consistency and accessibility. Iterative testing and refinement were conducted based on feedback from visually impaired users, ensuring the icons met their specific usability needs. User testing sessions provided valuable insights for refining the icons to ensure user-friendliness and practicality.

3.3 Research Hypothesis and Challenges

The hypothesis underpinning this research is that a universal standard for icon design will significantly improve software usability for visually impaired individuals, facilitating more straightforward navigation and interaction. The study also considers the diverse needs of visually impaired users, technical feasibility, and user adaptability to new designs as critical evaluative factors in developing and implementing standardized icons.

4. Ontology Construction

4.1 Ontology Design and Analysis

This phase thoroughly examined existing standards for graphical icons and an in-depth analysis of ontology definition procedures. We adopted the Toronto Visual Enterprise (TOVE) project methodology to ensure a comprehensive and systematic approach to constructing icon ontology (Figure 2). Using Protégé, we developed a standardized classification of icons, organizing them into tree structures. This process was crucial in understanding the relationships and functionalities of each icon within software environments.

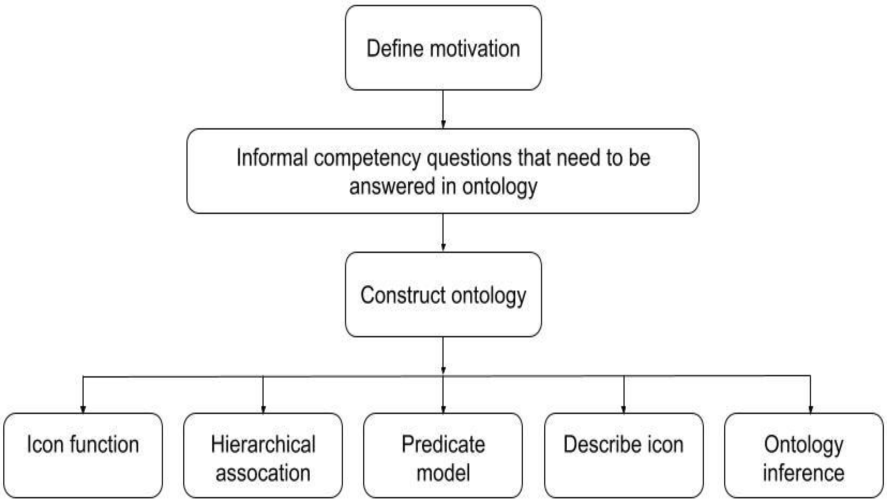

Figure. 2: Conceptual process of ontology construction with the TOVE project.

4.2 Ontology Development and Application

The development of the ontology was a multi-step process. Initially, we established the motivation for the project, focusing on the specific needs of visually impaired users. We then formulated informal competency questions to guide the construction process. The core of the ontology development involved creating a detailed hierarchical model, defining specific terminology, and developing predicate models and axioms. This comprehensive approach ensured the creation of a robust and functional ontology for icon classification (Figure 3).

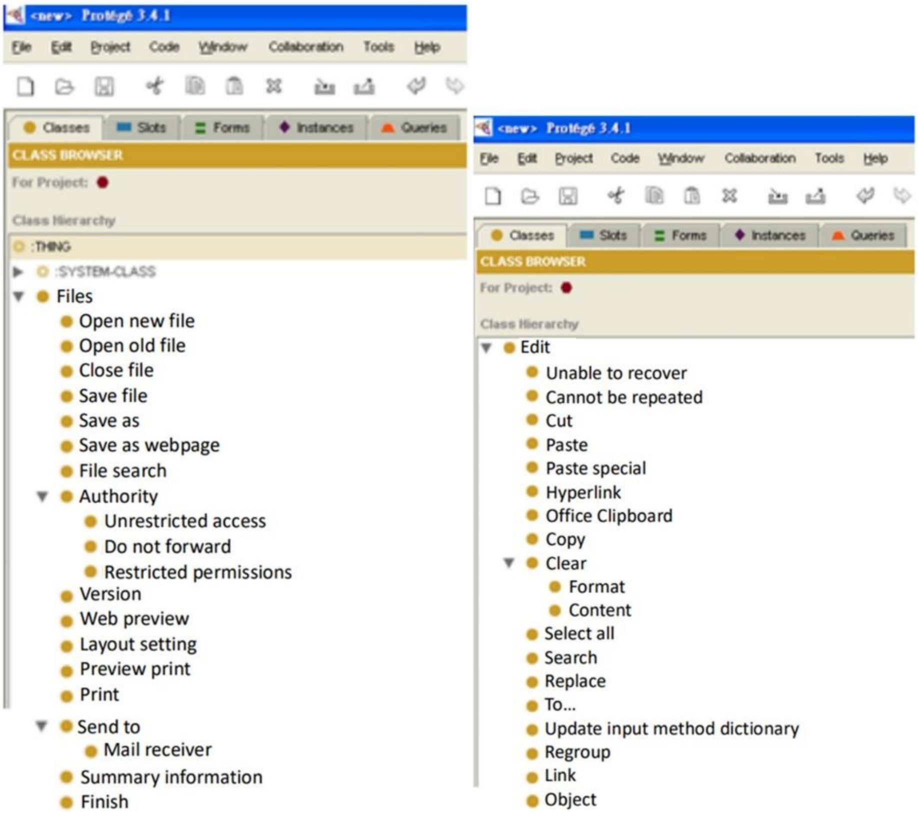

Figure 3. Relationship diagrams of the “File” class and expanded subclasses.

We also utilized Protégé to demonstrate the ontology's competency, thoroughly testing its ability to meet our objectives and answer the competency questions, thereby confirming its effectiveness and applicability in real-world scenarios (Figure 4).

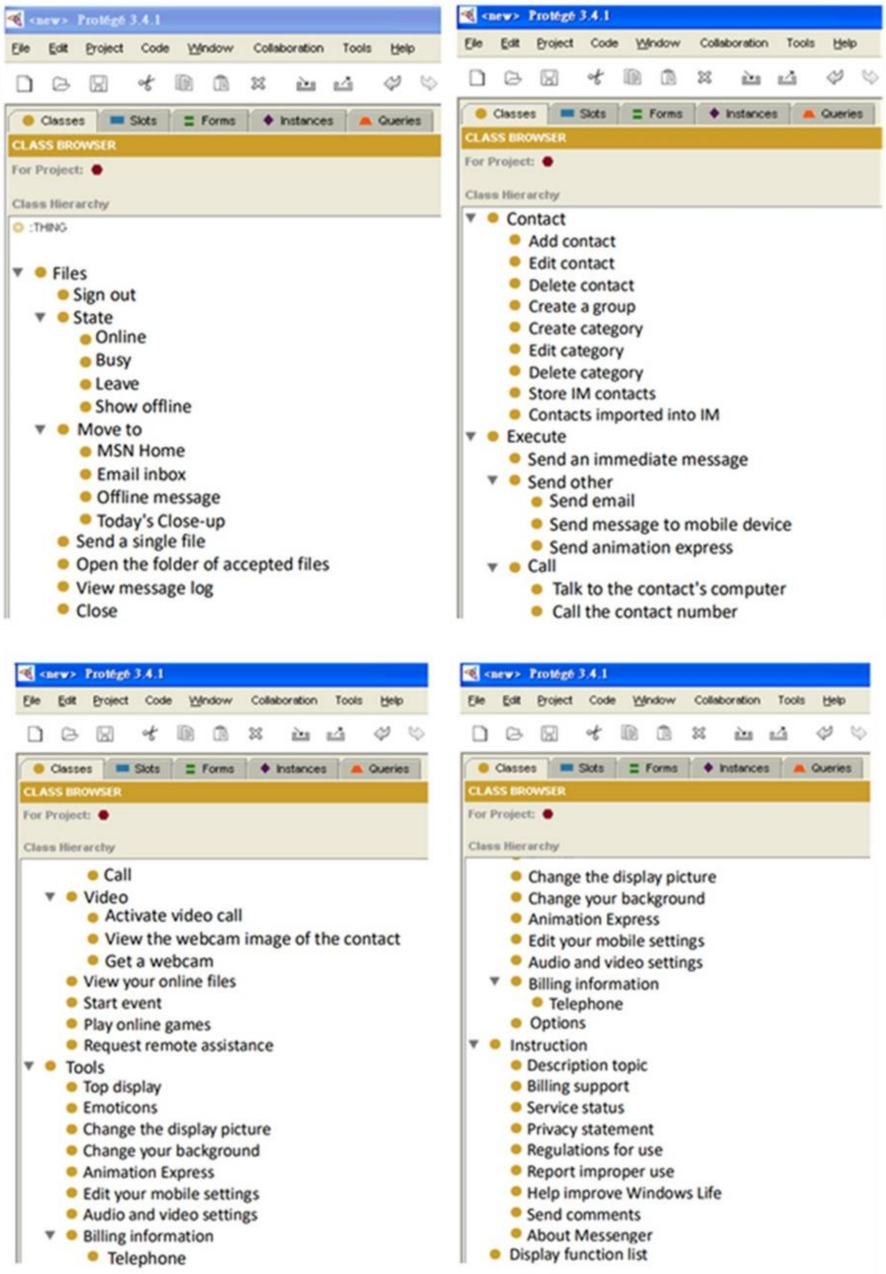

Figure 4. Relationship between icon functions in Messenger.

4.3 Icon Standardization and Implementation

The motivation behind using ontologies was to address the issue of disorganized icons in software programs, which mainly affects visually impaired users. Our goal was to standardize icon classification, facilitating software development and enhancing the communication of icon meanings through audio and braille outputs. This section also covers the practical application of these guidelines in software development, demonstrating how the standardized icons can be implemented in real-world applications to improve accessibility for visually impaired users (Figure 5)

Figure 5. Menu example" dialog box of the example program.

5. Conclusion

This study successfully established a comprehensive icon classification and software design standard, significantly enhancing accessibility for visually impaired individuals. Our research's key achievements, implications, and future directions are summarized below.

1. Enhanced Classification and Design Standards

Ontology-Based Classification: We developed an efficient method with user-friendly search functions, streamlining software organization and function identification (Jamil & Dénes, 2024). Software Design Standardization: We introduced a clear standard involving strategically renaming program header files, clarifying software functionality, and simplifying development. (Jamil & Dénes, 2024)

2. Recommendations and Industry Impact

Our findings underscore the importance of addressing diverse user needs, which can transform standard software development practices, particularly in accessibility design (Silva et al., 2019). Developers should prioritize comprehensive function items in header files to support the development of assistive technologies. This requires innovative engineering, user-centered design, and rapid development to meet the needs of users with cognitive disabilities (Braddock et al., 2004). Advocates, designers, and manufacturers must ensure future software and hardware systems are integrated, preventing assistive technologies from becoming obsolete. Universal design awareness and addressing non-technological barriers remain critical (Tobias, 2003). Finally, engineers should create accessible environments and devices, promoting equality in education, employment, and citizenship for disabled individuals (Burke et al., 2010; Braddock et al., 2004).

3. Future Research and Practical Applications

Extending Standards: Future research could explore applying these standards to various software types and platforms, enhancing overall accessibility.

Real-World Application Cases: Demonstrating the application of our methodologies in specific software development projects would showcase the tangible impact of improving accessibility.

4. User-Centric Evaluation and Limitations

User Feedback and Evaluation: Emphasizing results from user testing, particularly feedback from visually impaired users, adds credibility and highlights the practical effectiveness of our designs.

Acknowledging Limitations: Recognizing any limitations in our study provides a comprehensive understanding of our findings' context and scope.

In conclusion, our approach not only bridges a significant gap in accessible technology but also sets a foundation for more inclusive software design practices. By ensuring that visually impaired users can effectively interact with and understand software interfaces, our research contributes to a broader digital world.

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