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A semantic knowledge framework for squash in Nigeria: Design, implementation, and evaluation of a domain ontology

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Abstract

Despite squash's growing popularity in Nigeria and its recent recognition on the global stage, structured knowledge representation within the sport remains largely absent, particularly in the Nigerian context. This paper presents the design and implementation of a domain-specific ontology for squash in Nigeria, developed using Web Ontology Language (OWL) and implemented in Protégé. The ontology formalizes core entities and relationships associated with squash, such as players, competitions, training routines, equipment, and rules, while incorporating regional nuances in terminology and player development structures. Through a phased methodology combining expert interviews, literature analysis, and ontology engineering practices, the resulting model aims to support semantic search, knowledge reuse, data integration, and application development in sport analytics, education, and administration. Validation with domain experts demonstrates the ontology's practical value in organizing squash-related data, while also addressing broader gaps in the digital preservation of sporting knowledge in emerging economies. The study contributes to the literature on domain ontologies and cultural informatics, proposing a scalable foundation for representing sports heritage in underrepresented regions.

Keywords: Squash Ontology; Semantic Web; Knowledge Representation; Nigerian Sports; OWL; Cultural Informatics; Sports Analytics

1. Introduction

In an increasingly digitized and data-centric world, the need for structured, machine-interpretable representations of domain knowledge is central to advancements in artificial intelligence, semantic search, and intelligent systems. One of the core technologies enabling this shift is ontology engineering, which refers to the practice of developing formalized knowledge structures that define the concepts, entities, and relationships within a specific domain [1], [2]. In areas such as medicine, manufacturing, and education, ontologies have proven essential in supporting knowledge integration, sharing, and reuse across heterogeneous systems [3].

Although the sports domain has historically been underrepresented in ontology research, there is growing interest in using semantic technologies for purposes such as performance analysis, training optimization, and cultural preservation [4], [5]. Popular sports like football and boxing have particularly benefited from ontology-based modelling efforts [6]. However, squash, especially within developing countries such as Nigeria, remains relatively unexplored in this context.

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In Nigeria, squash was formally introduced in the 1970s and has experienced gradual growth through regional tournaments, grassroots development initiatives, and national competitions led by governing bodies such as the Nigeria Squash Federation. Despite these developments, the sport still lacks a centralized, structured, and digitalized knowledge base. This deficiency hinders effective data management, historical preservation, and semantic interoperability, while also limiting access to performance insights and coaching support. Consequently, valuable information is often lost or inconsistently documented across the squash ecosystem.

To address this gap, this study presents the design and implementation of an ontology specifically tailored to the squash domain in Nigeria. Developed using the Web Ontology Language (OWL) and the Protégé ontology editor, the model formalizes key domain concepts, including players, equipment, tournaments, coaches, rules, and events, while integrating local and contextual knowledge. The ontology was developed using established best practices in ontology engineering [8] and validated through both automated reasoning and expert feedback. Beyond technical modelling, the ontology also contributes to preserving Nigeria's squash heritage as a form of intangible cultural knowledge [9], [10].

The contributions of this work are threefold. First, it presents a domain ontology specifically developed for squash in Nigeria, capturing both globally recognized structures and culturally specific knowledge. Second, it demonstrates how semantic web technologies, particularly OWL-based ontologies, can be leveraged to organize and represent knowledge in underrepresented domains and regions. Third, it provides practical insights and methodological guidance for adapting ontology development processes to sports contexts with limited digitized resources.

2. Review of related works

2.1. Introduction

Ontologies have become vital instruments in knowledge engineering, allowing structured and semantically rich representations of complex domains. Their role in domains such as healthcare, digital humanities, and cultural heritage is well documented. However, within the domain of sports, especially less digitized sports like squash, the application of ontological methods remains underexplored. This section presents a thematic review of related works that inform the design and development of the squash ontology proposed in this study, focusing on ontology engineering in sports, cultural preservation, and semantic web frameworks.

2.2. Ontologies in Sports Knowledge Representation

The application of ontologies in sports domains is growing but remains largely centered around popular disciplines such as football, basketball, and boxing. For example, Lajçi et al. [4] developed a domain ontology for boxing using Protégé and OWL to structure entities like fighters, techniques, match outcomes, and training elements. Their approach leveraged SWRL rules and SPARQL queries to enable semantic querying and reasoning over boxing data, demonstrating the effectiveness of domain ontologies in sports analytics and historical archiving.

Similarly, El Raheb and Ioannidis [6] developed DanceOWL, an ontology framework for modelling choreography in performing arts, which supports content retrieval through semantic annotation. Though developed for dance, the methodology offers transferable value to other movement-based domains like squash, where player actions, techniques, and routines are central to domain semantics.

Football has also seen ontology-driven innovations. A notable example is presented by Bouayad-Agha et al. [7], who developed a framework for automatic football match summary generation using domain ontologies for content selection. These ontologies enable text generation systems to choose relevant content from structured knowledge bases, an approach that may prove useful for automatic reporting and commentary in squash.

2.3. Cultural Informatics and Sports Heritage

Preserving the intangible cultural heritage of traditional and emerging sports is increasingly becoming a concern in the digital humanities [9]. Hou and Kenderdine [5] argue that martial arts and traditional sports embody not just physical techniques but complex epistemologies encoded through bodily movement and socio-cultural interaction. Their study highlights the challenges of digitizing experiential knowledge and suggests ontology-based modelling as a viable solution for ensuring both preservation and accessibility.

The Hong Kong Martial Arts Living Archive, as described by Hou, Seydou & Kenderdine [10], serves as a leading example of ontology-guided cultural preservation. The archive uses motion capture, annotated multimedia, and formal ontology structures to preserve techniques, philosophies, and performance styles, offering a comprehensive digital record of a

traditionally oral and physical practice. These methods provide a valuable reference for modelling squash in Nigeria, especially considering the limited formal documentation in the domain.

2.4. Semantic Technologies for Intangible Sports Knowledge

Efforts to digitize traditional sports knowledge using semantic web technologies are gaining momentum. Zhang and Ala [11] developed a classification system for traditional sports as intangible cultural heritage (ICH) using AI, big data, and ontologies. Their framework supports content digitization, data annotation, and semantic querying for historical sports and community-based games. This intersection between digital preservation and ontology modelling demonstrates how underrepresented sports can gain visibility and structure through semantic technologies.

Further, Deng [12] explores the role of body phenomenology in sports philosophy, noting how experiential knowledge in sports is encoded through gesture, posture, and embodied cognition. The author's insights are especially relevant for the squash domain, where strategy, body positioning, and learned reflexes form much of the unstructured but crucial domain knowledge.

2.5. Challenges in Sports Ontology Design

Despite the potential, several challenges hinder ontology adoption in sports. According to Noy and McGuinness [8], a domain ontology must address heterogeneity in terminology, data fragmentation, and knowledge gaps from undocumented practices. These issues are particularly pronounced in squash in Nigeria, where data is scattered across informal channels, and the lack of structured training documentation has created barriers to knowledge sharing.

Moreover, Hou et al. [13] stress that ontologies in sports must accommodate temporal dynamics (e.g., rankings, match histories), multilingual vocabularies, and cultural variations, elements that generic sports ontologies often fail to capture. Thus, domain-specific, locally grounded ontologies are necessary to ensure relevance and applicability.

2.6. Gaps in Existing Literature

While the reviewed literature showcases significant strides in applying ontologies to sports and cultural heritage, no formal ontology exists specifically for squash, especially one grounded in the Nigerian context. The few semantic structures developed for sports tend to focus on global, professionalized, and data-rich disciplines. This gap underscores the novelty and necessity of the present work. By creating a Nigerian squash ontology, this study not only contributes to the underrepresented domain of squash but also provides a model for other locally practiced sports seeking structured semantic representation.

3. Methodology

3.1. Overview

This study adopts a design science research methodology to construct a domain ontology for squash in Nigeria. The process follows a systematic and iterative approach, drawing from best practices in ontology engineering as articulated by Noy and McGuinness [8], Antoniou and van Harmelen [2], and Uschold and King [14]. The methodology consists of four key phases: requirements gathering, ontology conceptualization, formalization, implementation, and evaluation. Each phase is underpinned by specific activities aimed at producing a reusable and validated knowledge structure tailored to the squash ecosystem in Nigeria.

3.2. Requirement Analysis and Domain Scoping

The first step involved defining the scope and domain boundaries of the ontology. The focus was limited to squash within the Nigerian sports system, with a particular emphasis on Oyo State as a representative case study. To accurately capture domain-specific knowledge, a combination of document analysis, expert interviews, and observation of squash tournaments was employed.

3.2.1. Data Sources

To inform the ontology development process, data was gathered from multiple complementary sources. First, a detailed document analysis was conducted, involving a review of official squash rulebooks, tournament guidelines, training manuals, and publications from relevant sports federations. This helped to extract standardized terminologies, domain-specific concepts, and operational rules governing squash in Nigeria.

In addition to documentary sources, semi-structured interviews were carried out with key domain experts, including experienced coaches, professional players, and officials from the Nigeria Squash Federation. These interviews were instrumental in capturing tacit knowledge, contextual nuances, and informal practices that are often absent from formal documentation.

Furthermore, existing ontologies in related domains were examined to identify reusable design patterns and modelling strategies. Notably, semantic models such as DBpedia [15], the Boxer Ontology developed by Lajçi et al. [4], and various cultural heritage ontologies provided valuable insights into structuring domain knowledge and linking entities effectively within a sports context.

3.3. Ontology Development Process

Ontology construction followed the "Ontology 101" methodology proposed by Noy and McGuinness [8], encompassing a series of structured steps to ensure logical consistency and domain relevance.

The process began with the formulation of competency questions to define the scope and practical use of the ontology. These included queries such as: *Who are the top squash players in Oyo State?*, *What equipment is required for junior tournaments?*, and *Which competitions follow specific national rules?* These questions provided clear criteria for evaluating the ontology's coverage and utility.

Next, key domain concepts such as Player, Tournament, Coach, Match, and Technique were identified and arranged into a hierarchical structure using a top-down modelling approach [16]. High-level classes were progressively refined into more specific subclasses, including ProfessionalPlayer, JuniorPlayer, and SeniorPlayer. Relationships among concepts were formalized through three types of properties. Object properties defined interactions between individuals (e.g., hasCoach, playsInTournament), data properties captured descriptive literals (e.g., age, gender, rank), and annotation properties provided metadata and documentation support (e.g., rdfs:label, rdfs:comment).

To support automated reasoning and validation, OWL axioms were introduced, including domain and range constraints, disjoint class declarations, and cardinality restrictions. For example, the class JuniorPlayer was restricted to individuals with an age property below 20.

Finally, the ontology was populated with real-world instances to demonstrate its applicability. These included individuals such as *Tunde Ajagbe*, a professional Nigerian squash player, and notable competitions like the *JVM Championship*. These instances allowed for practical testing of the ontology through SPARQL queries and reasoning engines.

3.4. Implementation Tools and Technologies

The squash ontology was implemented using Protégé 5.6.3, a widely adopted open-source ontology development environment that supports OWL 2.0. Protégé was selected for its robust visualization features, plugin extensibility, and compatibility with reasoning engines. It provided an intuitive interface for constructing classes, properties, individuals, and logical axioms, while also enabling ontology validation and documentation.

To ensure logical consistency and support inferencing tasks, HermiT 1.4 and Pellet reasoners were integrated within Protégé. These OWL-compatible reasoners allowed the ontology to be tested for classification accuracy, property restrictions, and inferred relationships between concepts. The Description Logic (DL) Query plugin was used to query the ontology using OWL syntax. This enabled complex questions, such as identifying players who have won specific tournaments or are within a particular age bracket, to be evaluated directly within the editor. In terms of query evaluation, SPARQL was used to construct semantic queries that validated the ontology's ability to retrieve domain-specific information. Sample queries included player statistics, match outcomes, and relationships among training entities.

The implementation was carried out in an environment running Java Runtime Environment (JRE 8), with the ontology development conducted on systems with Windows 10 and Ubuntu 20.04 operating systems. Web browsers such as Google Chrome and Mozilla Firefox were used to access documentation, community resources, and collaborative tools related to Protégé.

Overall, the combination of Protégé, OWL, reasoning engines, visualization plugins, and semantic query tools provided a comprehensive framework for the successful development, testing, and deployment of the squash ontology.

3.5. Ontology Evaluation and Refinement

The ontology was evaluated through expert validation and consistency checking. Three domain experts, two coaches, and one official from the Nigeria Squash Federation reviewed the ontology for completeness and relevance. Their feedback, collected via structured interviews, informed iterative refinements to improve accuracy and contextual alignment. In addition, OWL reasoners (HermiT and Pellet) were used to check for logical consistency. The ontology passed validation tests, confirming correct modelling of class hierarchies, disjointedness, and property constraints.

4. Results and evaluation

4.1. Ontology Design and Development Process

The development of the squash ontology followed a systematic implementation process grounded in well-established methodologies proposed by Noy and McGuinness [8] and Grigoris and van Harmelen [2]. The ontology was modelled using OWL 2.0 and implemented using Protégé version 5.6.3.

The process began with formally identifying key concepts relevant to squash in Nigeria, including entities such as *Player*, *Coach*, *SquashMatch*, *Equipment*, *Referee*, *Rule*, *Award*, and *Tournament*. A top-down design approach was adopted to develop the class hierarchy. High-level categories such as Person, Match, and Organization were refined into domain-specific classes like JuniorPlayer, SeniorPlayer, SquashTournament, and Coach. Inter-class relationships were defined through well-structured object properties (e.g., hasCoach, participatesInMatch, usesEquipment) and data properties (e.g., age, rank, nationality, dateOfCompetition). Semantic constraints, including cardinality, domain, and range restrictions, were applied to maintain internal consistency and logical correctness.

The complete ontology lexicon, comprising the full list of class hierarchies, object properties, and data properties, is summarized in Table 1.

Table 1 Ontology Lexicon: Key Classes, Object Properties, and Data Properties

Class Hierarchies	Object Properties	Data Properties
Awards	commentatesSquashMatch	age
State_Awards	playsInAmatuerSquashCompetition	city
State_trials	playsInProfessionalSquashCompetition	country
Player_of_the_Year	followsSquashRules	date
JVM_tournament	hasSquashStyle	division
Competitons	hasSquashTechnique	firstPlayer
Squash_Competitions	hasSquashCoach	firstName
Amatuer_Competitions	hasPhysician	fullName
State_Squash_Association	hasReferee	gender
Commonwealth_Games	hasWonAward	height
Professional_Competitions	isAbout	lastName
World_Squash_Association	participatesInMatch	nationality
Oyo_State_Squash_Association	sharesTechnique	nrOfLosses
All_Nigeria_Games	usesSquashEquipment	nrOfWins
Equipment		reach
Training_Equipment		residence
Racquet		result
Shoes		secondPlayer
Protective_Gear		venue

Goggles Wrist_band Headband Match Squash_Match Media Books Tutorial_videos Organizations Governing_Bodies Person Athlete Amatuer_Player Professional_Player Commentator Match_Commentator Umpire Rules Squash_Rules Styles Techniques Squash_Techniques		

Additionally, formal relationships between domain and range definitions for object properties were captured to support logical inferencing and knowledge structuring. These constraints are presented in Table 2 below.

Table 2 Object Properties with Domain and Range Constraints

Domain	**Object Property**	**Range**
Squash_Commentator	commentatesSquashMatch	Squash_Match
Amatuer_Player	playsInAmateurSquashCompetition	Amatuer_Competitions
Professional_Player	playsInProfessionalSquashCompetition	Professional_Competitions
Squash_Match	followsSquashRules	Squash_Rules
Player	hasSquashStyle	Squash_Styles
Player	hasSquashTechnique	Squash_Techniques
Player	hasSquashCoach	Squash_Coach
Squash_Match	hasPhysician	Squash_Physician
Squash_Match	hasReferee	Squash_Referee
Professional_Player	hasWonAward	Boxing_Awards
Media	isAbout	Player
Player	participatesInMatch	Squash_Match
Player	sharesTechnique	Player
Player	usesSquashEquipment	Squash_Equpment

4.2. Ontology Population

After defining the schema (TBox), the ontology was populated with individual instances (ABox) to represent real-world entities in Nigerian squash. These included notable squash players such as Tunde Ajagbe and Taofeek Afolabi, as well as prominent competitions like the JVM Championship and All Nigeria Games. Matches were instantiated with attributes such as venue, date, and participant details, while equipment classes captured gear like racquets, protective goggles, and wristbands.

This population phase enabled functional validation and querying of the ontology using SPARQL and the DL Query plugin in Protégé. Queries such as "Identify players from Oyo State who have won awards" or "List equipment used by junior players" confirmed the ontology's practical relevance in retrieving domain-specific information.

4.3. Visualization and Navigation

To aid structural understanding, the ontology was visualized using OWLViz and GraphViz plugins within Protégé. These visualizations provided both abstract and instance-level representations of relationships across the ontology.

Ontology metrics, including total classes, properties, and individuals, are shown in Figure 1, which demonstrates the scope and density of the model.

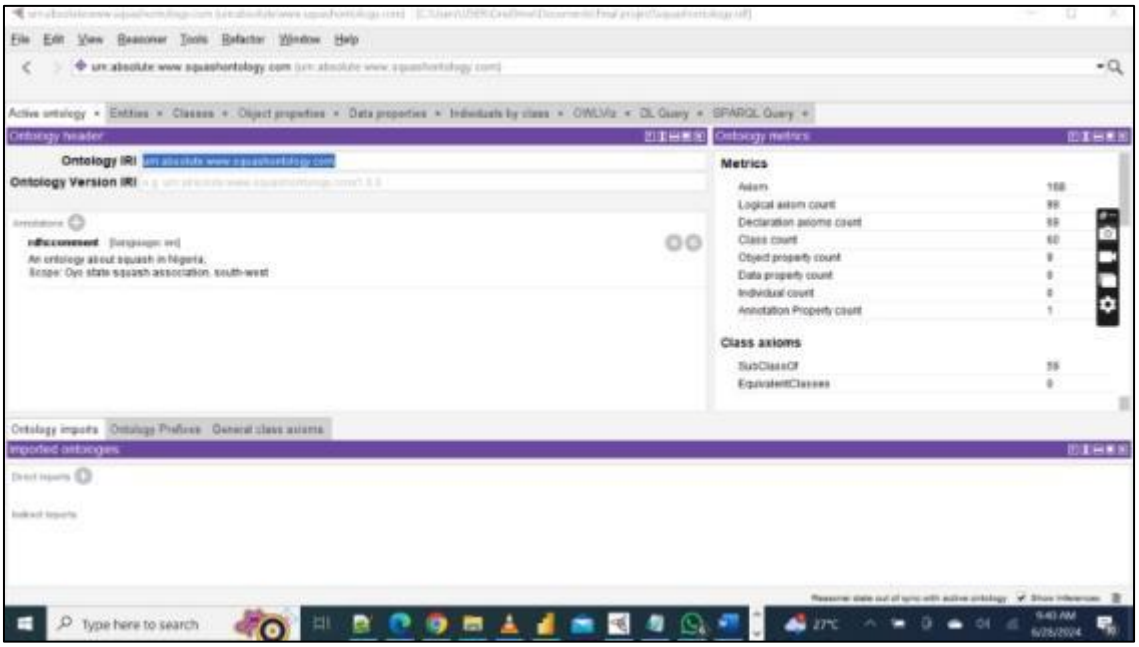

Figure 1 Ontology Metrics Summary

Further graphical representations of the class structure are illustrated in Figures 2–5. These figures show the raw class list (Figure 2), the graphical layout of class hierarchies (Figures 3–5), and how various subclasses are organized under parent concepts.

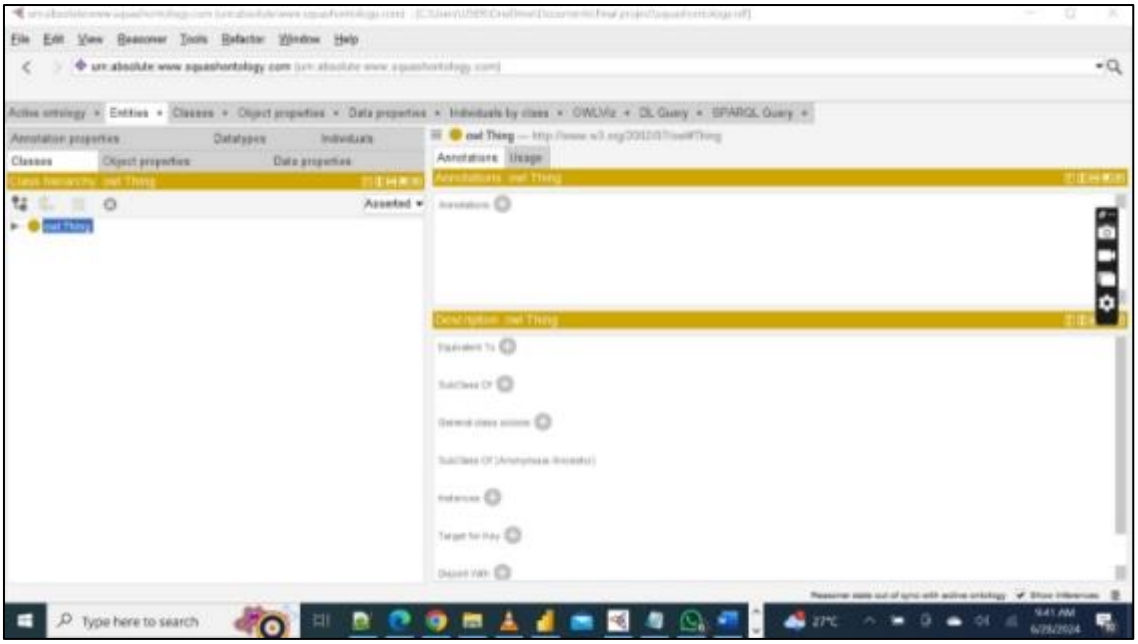

Figure 2 Classes

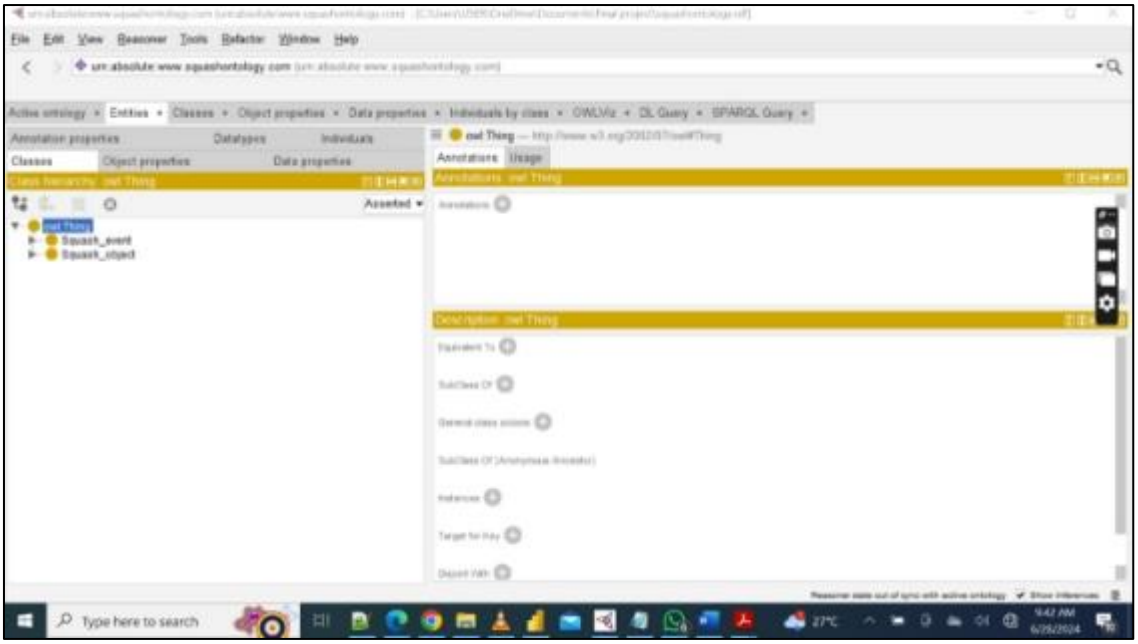

Figure 3 Classes list

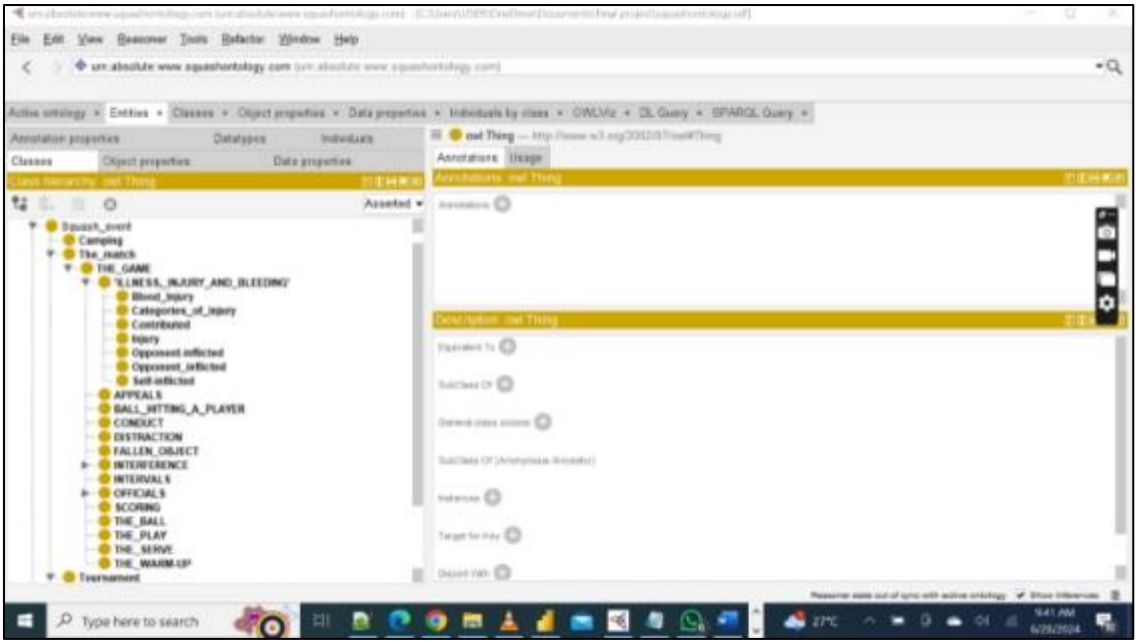

Figure 4 Class Hierarchy

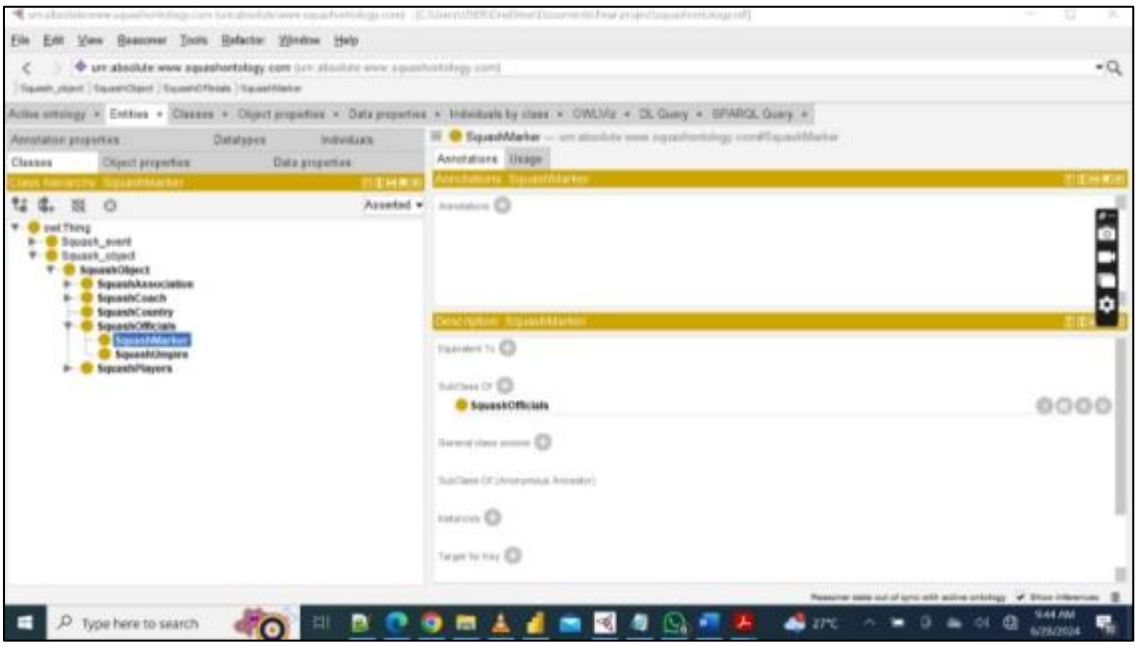

Figure 5. Class Hierarchy

object properties and their visual organization, crucial to representing domain semantics, are depicted in the Figures. 6 and 7, showing connections between entities such as players, equipment, coaches, and matches.

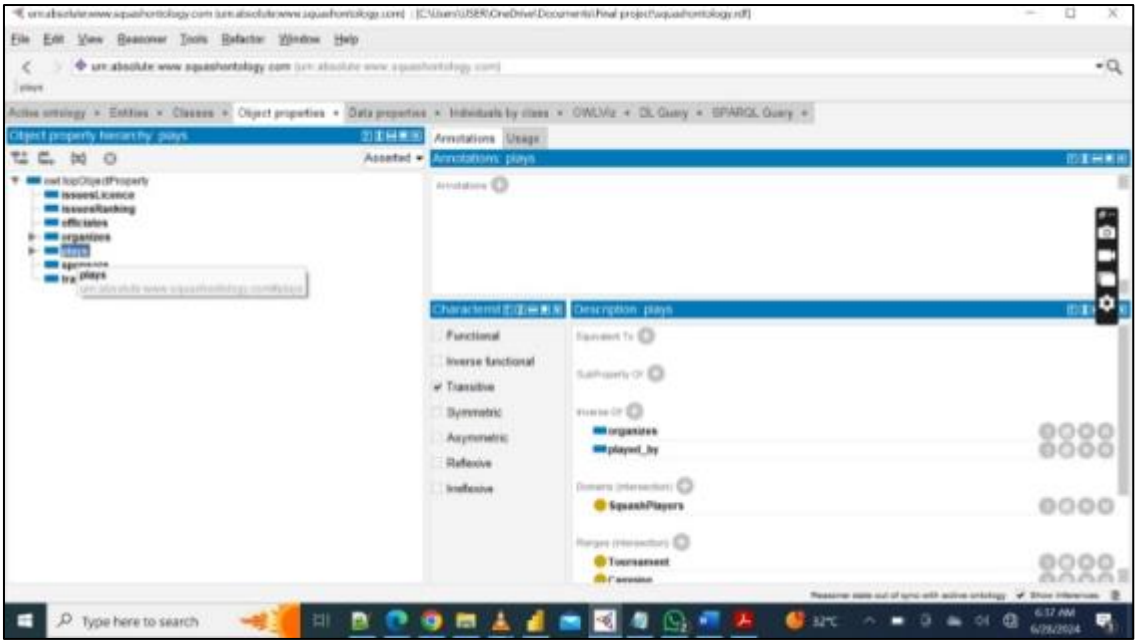

Figure 6. Object properties

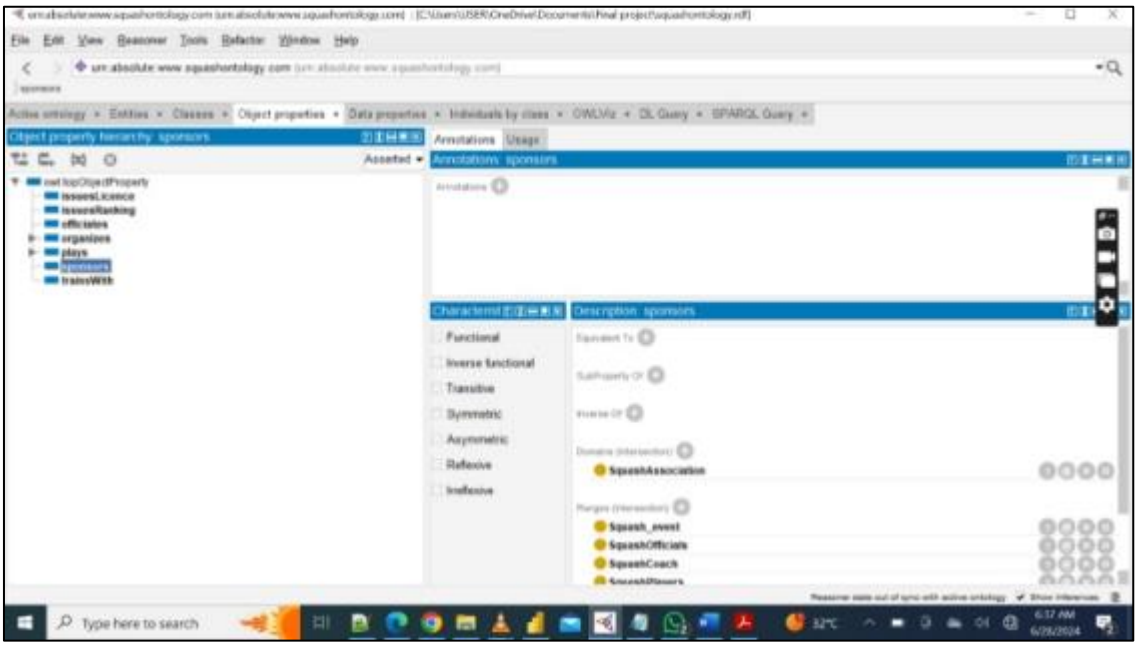

Figure 7 Object properties

To provide a semantic network visualization, GraphViz was used to display how individuals and objects are linked. For example, Figure 8 shows the relationship between players and their gear, while Figures 9–10 depict associations between tournaments, organizations, and match events.

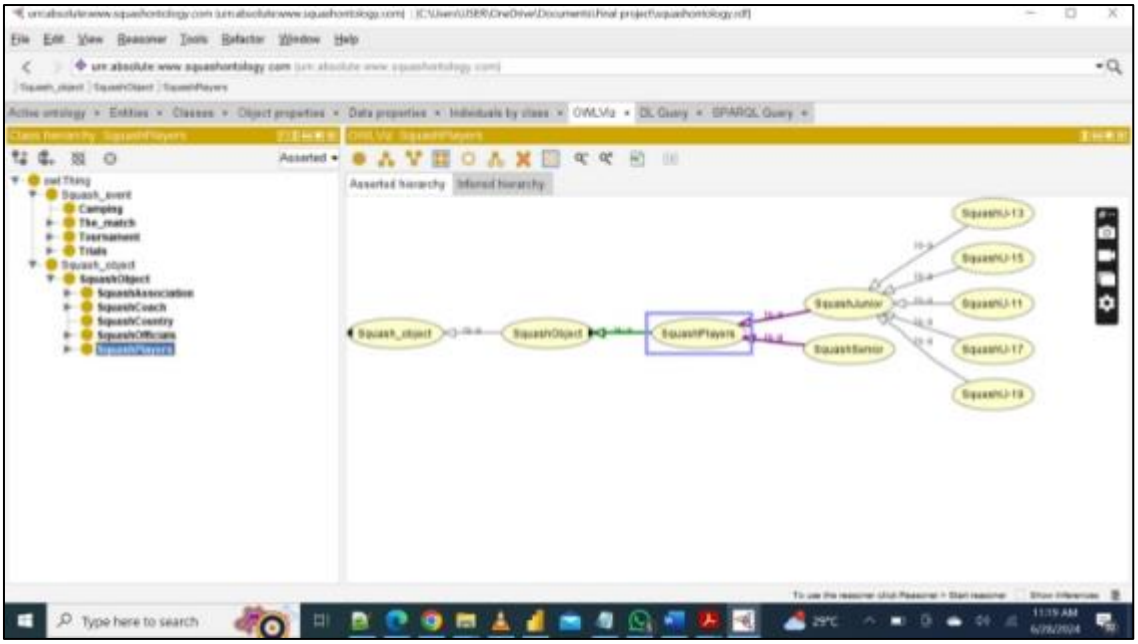

Figure 8 Graphviz display for Squash_object (players)

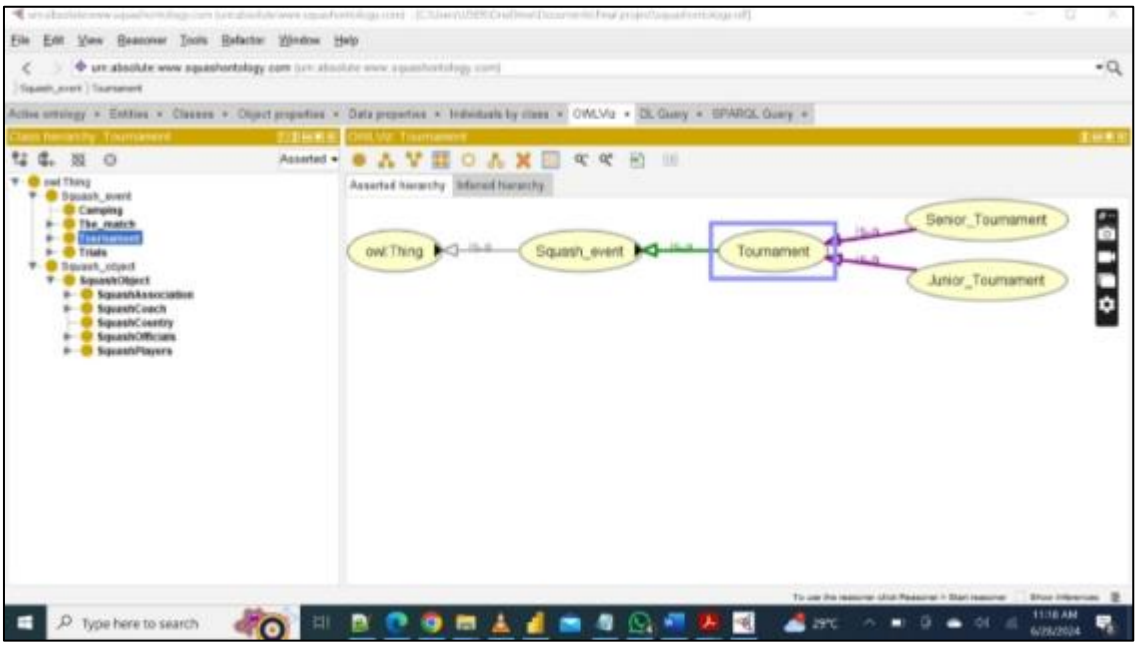

Figure 9 Graphviz display for Squash_event (tournament)

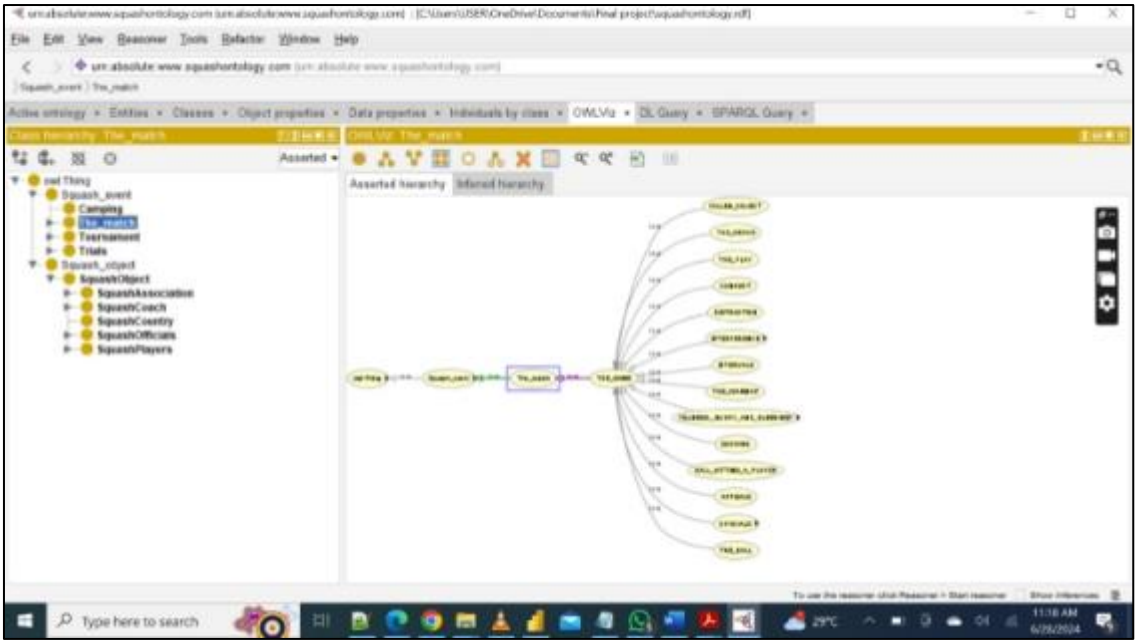

Figure 10 Graphviz display for Squash_event (match)

These visualizations not only improved ontology debugging but also served as effective tools for communicating the ontology's structure to non-technical stakeholders such as coaches and federation officials**.**

4.3.1. Expert Validation

The ontology was reviewed by three domain experts: two experienced squash coaches and one official from the Nigeria Squash Federation. These reviewers evaluated the comprehensiveness, accuracy, and usability of the ontology with respect to local terminology, training structures, and competition protocols. Their feedback highlighted the ontology's relevance and identified areas for minor refinement, such as incorporating indigenous training practices and modelling informal community leagues.

Following iterative improvements, the experts agreed that the ontology reflected a realistic and semantically accurate representation of squash in Nigeria. This validation reinforced the ontology's value as a foundational resource for both academic and practical applications in the sport. The implementation of the squash ontology involved formal modelling, data population, reasoning, visualization, and validation. The use of semantic web technologies enabled the development of a robust and extensible knowledge base that captures the unique aspects of squash in Nigeria. The ontology supports semantic querying, offers a structured foundation for application development, and provides a reusable model for similar initiatives in underrepresented sports domains.

5. Conclusion

This study has presented the design, implementation, and evaluation of a domain ontology for squash in Nigeria, a sport whose growing popularity contrasts sharply with the lack of structured, digital knowledge representation. The ontology was developed using OWL 2.0 and implemented in Protégé, guided by established ontology engineering methodologies and refined through iterative validation with domain experts.

The ontology captures key entities and relationships within the Nigerian squash ecosystem, including players, tournaments, equipment, referees, and coaching systems. Through logical modelling and the use of reasoning tools, it supports accurate semantic queries and enables the discovery of implicit knowledge. Moreover, the ontology integrates both formal and tacit knowledge, addressing regional nuances in terminology, competition structure, and player classification.

The outcome is a reusable, scalable, and semantically rich framework that not only improves information organization and retrieval in squash but also contributes to the broader goals of sports knowledge management, digital preservation,

and semantic interoperability. As one of the first structured efforts to digitally formalize squash knowledge in an African context, this work fills a critical gap in the semantic web and sports informatics literature.

5.1. Contributions of the Study

This study offers several notable contributions across theoretical, technical, practical, and cultural dimensions. From a theoretical perspective, it extends the application of semantic web technologies to a relatively under-explored sports domain. By developing a formal ontology specifically for squash in Nigeria, the study demonstrates how ontology engineering can be effectively grounded in local practice and adapted to represent region-specific knowledge structures.

Technically, the work showcases the successful implementation of a functional OWL ontology using widely accepted tools such as Protégé, GraphViz, and the HermiT reasoner. This implementation serves as a replicable model for researchers and developers aiming to undertake similar projects in low-resource or domain-specific contexts where digital infrastructure and structured data are scarce.

Practically, the ontology has immediate relevance for stakeholders such as sports administrators, coaches, and software developers. It supports the development of intelligent applications in areas like player profiling, tournament planning, equipment tracking, and performance analytics, thereby offering data-driven solutions for managing and advancing squash programs.

Culturally, the ontology plays a vital role in preserving Nigeria's squash heritage. By capturing local terminologies, informal training practices, and organizational structures, it provides a foundation for long-term knowledge retention and facilitates the inter-generational transfer of expertise within the sport. In doing so, it contributes to safeguarding intangible cultural assets that might otherwise be lost in the absence of structured documentation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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