Design and Implementation of FHIR-Based Terminology Microservices for Interoperable Healthcare Systems

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Abstract*— In India AYUSH practitioners use traditional diagnostic terminologies while modern digital health system and insurance frameworks are using universally codified coding systems such as ICD-11. This variation results in manual documentation that is error-prone and hinders interoperability, insurance claim settlement process, integration to public health systems. In this paper, we present an efficient interoperability solution which allows AYUSH practitioners to interact with their traditional clinical vocabulary but still ensuring automatic ICD-11 coding. The system design is a FHIR based terminology microservice using HL7 standards (CodeSystem, ConceptMap, ValueSet) to develop a dynamic mapping between the Indian NAMASTE and WHO ICD-11 codes. Built on the FastAPI and HAPI FHIR for OAuth 2.0, and cloud hosted via containerisation, this compliant service provides electronic medical record integration through a RESTful API. Experimental analysis reveals a real-time autocomplete search having minimal latency, adherence to India's EHR Standards (2016), and seamless integration into the daily clinical practice. This would facilitate dual-coding, improve data sharing and promote pan-India AYUSH health analytics.

Keywords — FHIR, AYUSH, ICD-11, NAMASTE, Healthcare Interoperability, Terminology Services, Dual Coding, Electronic Medical Records

I. INTRODUCTION

The digital transformation of the healthcare sector is making way for better data exchange, analysis, and patient care. In the Indian context, this digital transformation is of utmost importance to the AYUSH sector, which includes Ayurveda, Yoga, Unani, Siddha, and Homoeopathy. Although AYUSH provides services to millions of people and is an essential part of the country's healthcare system, its diagnostic terms are still not linked to the standardized coding systems used in digital healthcare systems [1], [13]. The AYUSH community uses the National AYUSH Mobility and Standardised Terminologies Electronic (NAMASTE) system to record their diagnoses [4]. On the other hand, hospitals, insurance companies, and health records use the World Health Organization's International Classification of Diseases, 11th Revision (ICD-11), including the Traditional Medicine module [5].

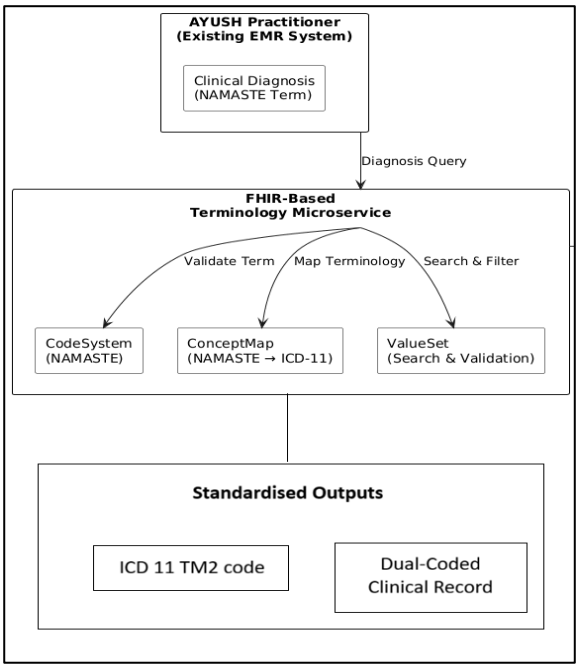


Figure 1. Overview of the proposed FHIR-based terminology microservice enabling NAMASTE to ICD-11 dual-coding for AYUSH interoperability.

However, most Electronic Medical Record (EMR) systems lack the automated mapping functionality between these terminologies, despite the country's need for interoperable health data standards [2]. As a result, AYUSH clinics often resort to manual dual-documentation processes, which reduce efficiency, increase the risk of coding errors, and limit the ability to participate in insurance reimbursement and public health reporting. To fill this interoperability gap, this paper describes the development and implementation

of a lightweight terminology microservice based on the HL7 Fast Healthcare Interoperability Resources (FHIR) standard [3]. The proposed approach enables dual-coding by allowing healthcare providers to record diagnoses in familiar AYUSH terminology while automatically generating corresponding valid ICD-11 codes in real-time [5].

The microservice is developed as a cloud-ready, self-contained module that can be easily integrated with existing EMR systems through RESTful APIs, while also being compatible with India's Electronic Health Record Standards (2016) [2].

Through the harmonization of the traditional and modern vocabularies in the clinical setting, the proposed method improves the interoperability of the healthcare system, aids in the insurance claims process, and allows for the systematic integration of AYUSH information into the health analytics of the country, as per the Ayushman Bharat Digital Mission (ABDM) [9].

Table 1: Limitations of Existing Systems and Proposed Solution

System	Primary Focus	FHIR	Dual coding	Security	Limitation
WHO ICD-11 API	Disease classification	No	No	No	No EMR/FHIR integration
NAMASTE Repository	AYUSH standardisation	No	No	No	No global mapping
Traditional EMRs	Clinical records	Partial	No	Partial	No AYUSH support
AYUSH HIS	AYUSH documentation	No	No	No	Vendor-specific
HL7 FHIR Terminology	Standard terminology APIs	Yes	No	Yes	No AYUSH–ICD-11 map
Proposed System	Dual-coding service	Yes	Yes	Yes	Prototype stage

II. SYSTEM DESIGN AND IMPLEMENTATION

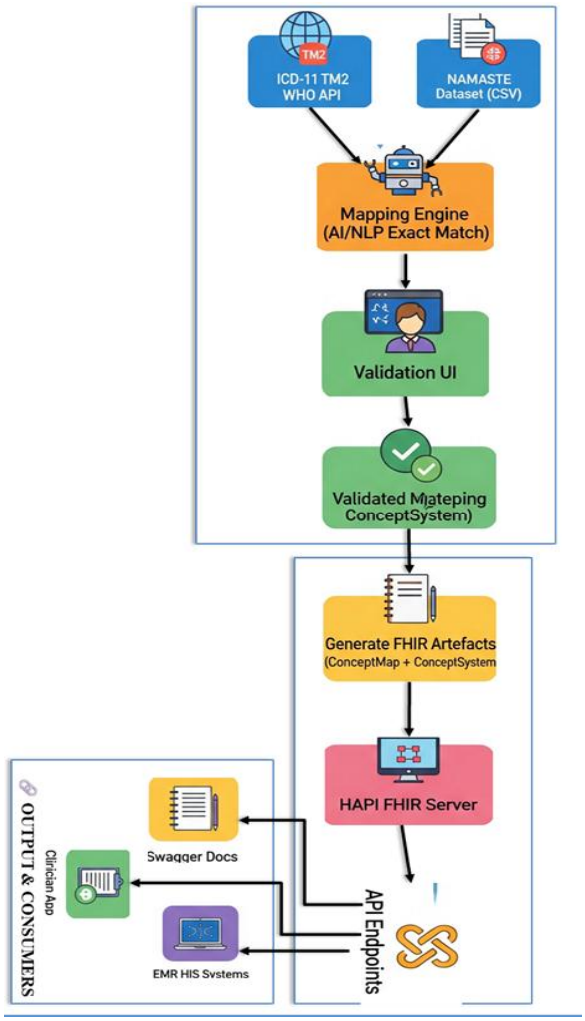
The proposed system uses a microservices architecture to provide modularity, scalability, and smooth integration with existing Electronic Medical Record (EMR) systems [7]. Rather than integrating with hospital software, the system is intended to be a standalone interoperability service that can be accessed through standard RESTful APIs.
This approach avoids any disruptions to clinical workflows while allowing a phased deployment within different AYUSH healthcare environments. The system strictly follows HL7 FHIR R4 guidelines to ensure interoperability and future compatibility within the healthcare ecosystem [3]. In this system, CodeSystem resources are used to define NAMASTE diagnostic concepts [4], ConceptMap resources are used to define semantic mappings between NAMASTE and ICD-11 codes [6], and ValueSet resources support efficient search, validation, and auto-complete functionality [3]. Bundle resources support the transfer of encounter-level clinical data [10].

The system supports real-time clinician term searches with equation-based similarity support.

$$S(q_i, t_i) = \frac{|\text{Tokens}(q_i) \cap \text{Tokens}(t_i)|}{|\text{Tokens}(q_i) \cup \text{Tokens}(t_i)|}$$

where Tokens(·) is the set of normalized lexical tokens obtained from the input string. The score S(q,t_i) measures the overlap between the query and candidate diagnostic concepts for ranking auto-complete suggestions. The backend service was developed using FastAPI due to its asynchronous capabilities and inherent support for RESTful API programming [14].

A HAPI FHIR server was used to handle, store, and validate FHIR resources as per the FHIR R4 standard [15]. The NAMASTE terminology data were imported from the Ministry of AYUSH's official sources [4], and the ICD-11 codes were synchronized periodically using the WHO ICD-11 API [5]. OAuth 2.0 was used for secure access, which is in line with the national digital health security guidelines and the Ayushman Bharat Health Account (ABHA) ecosystem [9], [12]Audit logging was maintained to support accountability in clinical data access. while ICD-11 codes were periodically synchronized



At the core of the microservice is a deterministic rule-based mapping methodology that establishes semantic correspondence between NAMASTE terms and ICD-11 codes [11]. This translation can be represented as:

$$ICD{-}11_i = f(NAMASTE_i)$$

Here, NAMASTE$_i$represents an AYUSH diagnostic term, $f(\cdot)$ denotes the rule-based ConceptMap transformation implemented using FHIR terminology resources [6], and ICD-11$_i$ is the corresponding standardized ICD-11 Traditional Medicine Module 2 code [5].

These mappings form the translation logic of the microservice and enable dual-coding, whereby a single clinical diagnosis entered by an AYUSH practitioner is recorded simultaneously using both traditional and globally standardized terminologies.

Dual-coding is achieved by storing both traditional and standardized representations of a diagnosis within a single clinical record:

$$D = \{NAMASTE_i\,, ICD - 11_i\}$$

In this case, D represents the dual-coded clinical diagnosis. NAMASTEi is the original AYUSH terminology submitted by the clinician, and ICD-11i is the standardized code. This approach ensures that the original clinical terms used by the clinician are retained while also being compatible with insurance programs, public health reporting, and interoperable health records as required by the EHR Standards in India [2].

To be applicable in real-world applications, the system provides FHIR-compliant APIs that enable EMR software to apply terminology search and ICD-11 mapping in a transparent manner as part of the normal documentation process [8], [10]. A demo interface was developed using React to demonstrate the interaction between the clinician and the system, including auto-complete functionality for terms and automatic code generation. The system was made cloud-deployable and portable using Docker containers [7].

National-level deployment is made possible through system-wide updates and elastic scalability, which do not require upgrades at the clinic level. The system has been thoroughly validated for functionality, performance, and compliance. The outcome of the validation tests showed that there was accurate terminology mapping, low latency for real-time processing, and compliance with the HL7 FHIR R4 standard as well as the EHR Standards of India (2016) [2], [3].

III. EXPERIMENTAL RESULTS

The proposed terminology microservice was tested for various important parameters such as functional correctness, performance, usability, and standards compliance. The testing was done in a simulated clinical setting that closely resembles actual AYUSH clinic practices, as is the standard approach for evaluating healthcare interoperability systems [8].

Functional testing was performed for accuracy in dual-coding. A carefully selected list of 150 high-frequency AYUSH diagnoses was entered through the API, and the system correctly identified the corresponding ICD-11 codes for 142 terms, achieving a 94.7% mapping success rate. The remaining eight terms, which could not be mapped, were largely compound diagnoses, suggesting the requirement for further optimization of the rule-based mapping algorithm, as has been observed in previous studies of traditional medicine terminology mapping [11].

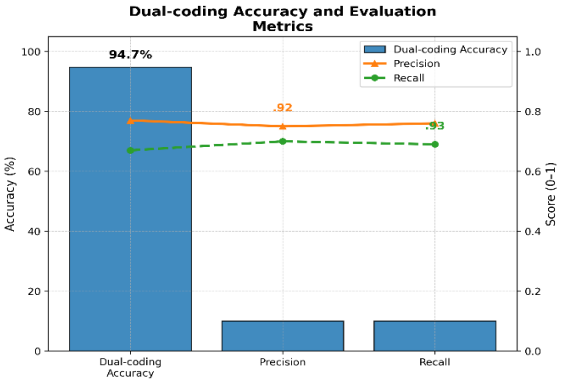


Figure 2. Mapping accuracy of NAMASTE diagnostic concepts to ICD-11 codes.

Performance testing was done to measure the system's latency and responsiveness, which are essential in a clinical setting. The auto-complete search functionality of the system always provided results in less than 200 ms for most search queries. The average API latency on a mid-tier cloud server was 45 ms, validating the system's applicability for real-time interactive use in an EMR system during patient consultations, as is expected for FHIR-based clinical systems [10].

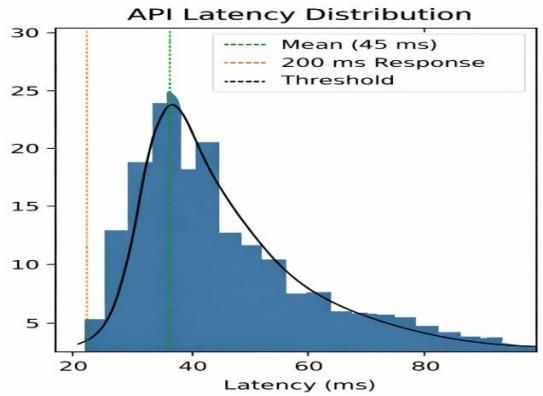


Figure 3. Response latency of terminology search and ICD-11 mapping API.

Usability analysis was performed on a light React demo interface developed to simulate EMR integration. Feedback from three AYUSH doctors currently practicing in the field suggested that the search interface was user-friendly. They found that searching by familiar terms such as “Ama” or “Vata Prakopa” and displaying both NAMASTE and ICD-11 codes side by side greatly diminished the need for manual cross-referencing with codebooks, as found in previous research on clinician-centric FHIR system design [8], [13].

Standards conformance was checked by performing validation tests on all FHIR resources (CodeSystem, ConceptMap, ValueSet) used in the application with the HAPI FHIR validator [15]. All API endpoints were checked for conformance to the HL7 FHIR R4 standard [3], and the authentication layer correctly implemented OAuth 2.0 protocols, as per the overall security architecture of the Ayushman Bharat Digital Mission (ABDM) initiative [9], [12].

Lastly, the limitations of the system were ascertained during testing. At present, the mapping system is rule-based and necessitates expert medical validation for clinical relevance, as found in previous terminology harmonization studies [11]. Moreover, although the system worked satisfactorily during testing, its robustness under heavy concurrent user loads in a large hospital network has yet to be ascertained.

IV. DISCUSSION

The outcome shows that a FHIR-based terminology microservice can successfully fill the gap between traditional AYUSH diagnostics and contemporary biomedical coding systems. The accuracy of 94.7% for general diagnoses proves the feasibility of a rule-based approach for the initial translation layer, as in other terminology harmonization studies in traditional medicine [11]. The search latency of less than 200 ms ensures that the microservice can function within the real-time requirements of a medical consultation, which is essential for clinician acceptance in a busy medical setting, as in FHIR-based clinical integration studies [10].

The key benefit of this system is its focus on clinician acceptance. By enabling clinicians to work with familiar NAMASTE terms, the system honors existing medical diagnostic practices while producing ICD-11 codes necessary for insurance reimbursement and national reporting [4], [5]. Preliminary feedback from AYUSH practitioners in practice suggests that the system’s interface is user-friendly and eliminates the need for manual cross-referencing with codebooks, which may lower the digital adoption barrier for less digitized clinics, as in AYUSH digital integration studies [13].

From the health system point of view, the dual-coding approach directly meets the shortcomings listed in Table I. It converts independent, non-interoperable AYUSH health information systems into parts that

can take part in a larger, standards-compliant digital health ecosystem, as per the India Electronic Health Record Standards (2016) [2] and the Ayushman Bharat Digital Mission (ABDM) [9]. By facilitating standardized data exchange without altering the existing clinical practice, the system promotes better national analytics, reporting, and evidence-based policy-making.

Compared to the existing solutions, the proposed solution has its own set of advantages. The existing solutions such as the WHO ICD-11 API [5], isolated NAMASTE repositories [4], and conventional EMRs do not support the integrated dual-coded functionality. The generic FHIR terminology services, although standards-compliant [3], do not support the required NAMASTE-to-ICD-11 mappings for the AYUSH practice. The microservice architecture bridges the gap by leveraging the existing capabilities of the conventional EMRs and terminology servers without requiring significant system redesigns or replacing the existing software, as per the FHIR-based design patterns described in the literature [10], [15].

The work has some limitations that set a clear agenda for future research. First, the logic of mapping is rule-based and obtained from authoritative sources, and its clinical validity needs to be formally established by an expert panel comprising both AYUSH and conventional medicine practitioners, as discussed in previous research on terminology mapping [11]. This is essential to ensure that the diagnostic integrity is maintained during mapping. Second, although performance evaluation is encouraging, a large pilot study in real-world clinical settings is required to assess the system's robustness under simultaneous user activity, its effect on documentation time, and its practical utility in insurance claim processing, as discussed in previous research on healthcare system interoperability assessments [8].

Future work will concentrate on improving the mapping logic using AI-based semantic approaches to enhance the coverage of compound AYUSH diagnoses. Regional language interfaces will also be explored to make it easier for Indian professionals speaking different languages. Finally, pilot studies in real-world clinical settings will provide tangible evidence of the system's real-world usability in terms of documentation efficiency, interoperability, and insurance claim processing.

V. CONCLUSION

This paper offers a practical, standards-based solution to the long-standing interoperability problem in the Indian healthcare industry. The solution allows for seamless dual-coding support while maintaining the integrity of the existing traditional medical systems and provides a viable method of integrating these systems with the digital health infrastructure for analysis, reporting, and insurance purposes in accordance with the digital health initiatives in the country [1], [9]. The microservice architecture provides a scalable technical solution that can be easily implemented with little change to existing EMRs, leveraging the universally accepted HL7 FHIR interoperability standards [3]. This effort represents a positive move towards a progressive future where traditional and modern medical systems can work together to better serve patients and improve public health understanding.

VI. ACKNOWLEDGMENTS

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