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Short Communication

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Tympanoplasty Diagnostic Platform - Project Outline

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Abstract

Objective: This project outline focuses on the AI-based analysis of individual pressure-less acoustic immittance (PLAI) measurements. The rationale is that the interpretation of individual measurement values—such as the resonance frequency of admittance—depends on the anatomical characteristics and pathologies of the ear canal, the tympanic membrane, and the middle ear. Therefore, the goal is to leverage findings from the external auditory canal, tympanic membrane, and middle ear to create a diagnostic platform for middle ear diagnostics. This platform will enable clinicians to accurately interpret the findings and provide prognostic information regarding the success rate of tympanoplasty.

Materials and Methods: This project outline details the engineering stack, enterprise cloud services, artificial intelligence engines, and pipeline integrations used to build the Tympanoplasty Diagnostic Application. The application is designed as a cloud-native, microservices-ready platform deployed on the SAP Business Technology Platform (SAP BTP), which is further created to ingest high-dimensional multi-frequency acoustic datasets, calculate real-time statistical normalizations, execute parallel multi-model generative AI evaluations, and export dynamic reports in PDF and Microsoft Word formats.

Expected Results: The project outline will deliver a production-ready enterprise software architecture that combines the following: SAP enterprise standards, including native SAP BTP Cloud Foundry deployment with XSUAA OAuth2 security and integration of the Generative AI Hub; a multi-engine AI triad that benchmarks OpenAI GPT-4o, Anthropic Claude 3.5 Sonnet, and Microsoft BioGPT simultaneously; fault-tolerant microservices that involve error handling for outgoing DNS requests and feature a fault-tolerant heuristic in-memory pipeline; and full traceability from raw table rows to records in relational databases, thus culminating in summaries of AI inference and one-click PDF/Word exports.

Introduction

Pressure-less acoustic immittance (PLAI) measurement is a method in which a probe is inserted into the ear canal to allow the clinician to routinely receive the resonance frequency (Fres or F) and peak of admittance (Peak) [1-5]. For research purposes, additional factors such as acoustic ear volume (Vea), bandwidth height (Bnd), and quality factor from bandwidth (Q) are derived from the measurements and used for analysis. Vea is automatically calculated from Fres by the device using a proprietary, empirically derived calibration function [1].

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This project outline emphasizes the AI-based evaluation of individual PLAI measurements. The interpretation of these measurements, such as the resonance frequency of admittance, is influenced by the anatomical conditions and pathologies of the ear canal, tympanic membrane, and middle ear. Therefore, the aim is to utilize findings from the external auditory canal, tympanic membrane, and middle ear to create a diagnostic platform for middle ear diagnostics that enables clinicians to accurately interpret findings and provide prognostic information regarding the success rate of tympanoplasty.

Materials and Methods

Ethical Considerations

The study is being conducted in accordance with the Declaration of Helsinki.

Executive Technical Overview

This document outlines the engineering stack, enterprise cloud services, artificial intelligence engines, and pipeline integrations used to build the Tympanoplasty Diagnostic Application. The application is designed as a cloud-native, microservices-ready platform deployed on SAP Business Technology Platform (SAP BTP), which is further intended to ingest high-dimensional multi-frequency acoustic datasets, calculate real-time statistical normalizations, execute parallel multi-model generative AI evaluations, and stream dynamic reports in PDF and Microsoft Word formats.

2. Full Technology Stack & Dependencies

The application is built on modern enterprise software standards with a clear separation of concerns between ingestion, business logic, AI orchestration, and client rendering:

Table

Layer / Domain	Technology / Library	Role & Engineering Function
Cloud Platform	SAP BTP Cloud Foundry	Enterprise runtime hosting, container life cycle management, environment binding.
Backend Runtime	Nodejs	Asynchronous HTTP routing, REST API controllers, streaming binary downloads.
Enterprise Security	SAP XSUAA & @sap/xssec	OAuth2 / JWT token validation, enterprise user principal binding, Passport.js middleware.
AI Orchestration	SAP AI Core / Azure OpenAI	Generative AI Hub integration, token exchange, deployment management for GPT-4o.
Specialized AI	Hugging Face Serverless	REST router client for biomedical domain models (BioGPT) with fail-safe heuristics.
Relational Database	PostgreSQL / SAP HANA	Structured cohort schema, visit audit logging, multi-parameter state persistence.
Object Storage	Azure Blob Storage SDK	Blob client archiving raw uploaded binary datasets (.ods, .xlsx) with timestamps.

3. SAP BTP Cloud Infrastructure & Services

The deployment leverages the SAP BTP ecosystem to achieve enterprise-grade security and reliability.

• **SAP BTP Cloud Foundry Environment:** The application is packaged and deployed using Cloud Foundry CLI ("cf push"). Resource limits, application routing, and environment variables are orchestrated using the BTP Cloud Foundry router.

• **SAP XSUAA Service Binding:** Authentication is governed by SAP's extended Authorization and Trust Management service (XSUAA). In cloud environments, incoming requests pass through the Approuter and are authenticated via JWT bearer tokens verified through "@sap/xssec" and Passport strategies. A dual-mode bypass allows seamless local development without compromising cloud guards.

• **VCAP_SERVICES & Secret Ingestion:** All service keys, database credentials, and storage connection strings are read dynamically from the "VCAP_SERVICES" container environment, thus preventing any hardcoded secrets in the source code.

4. AI Engines & Model Taxonomy

Rather than relying on a single model, the platform implements a multi-engine AI architecture that incorporates the following three distinct AI categories to compare reasoning and validate outputs:

A. Frontier Foundation Model: OpenAI GPT-4o via SAP AI Core

• Architecture: Large Multimodal Transformer / Advanced Autoregressive LLM.

• Hosting / Provider: Hosted within SAP AI Core (Generative AI Hub) with Azure OpenAI fallback.

• API Integration: Authenticates to SAP AI Core by trading client credentials with the SAP OAuth service, then calls the deployment route: "/v2/inference/deployments/{deployment Id}/chat/completions."

• Core Responsibility: Acts as the primary diagnostic reasoning engine that generates structured four-point clinical research narratives, detects anomalies across sensor parameters, and calculates dynamic post-op prognosis timelines.

Object Storage (Azure Blob Storage SDK): Blob client archives raw uploaded binary datasets (.ods, .xlsx) with timestamps.

B. Advanced Reasoning Model: Anthropic Claude 3.5 Sonnet

• Architecture: Next-generation constitutional foundation model optimized for technical reasoning and long-context coherence.

• Hosting / Provider: Anthropic API / SAP AI Core GenAI Hub Gateway.

• API Integration: Interfaced via native JSON message payload ("/v1/messages") with custom system prompt enforcement.

• Core Responsibility: Serves as a comparative biomechanical second opinion, cross-verifying resonance frequency shifts against stiffness versus hypermobility patterns.

C. Domain-Specific Transformer: Microsoft BioGPT

• Architecture: Domain-specific generative pre-trained transformer trained exclusively on millions of biomedical research papers (PubMed/MEDLINE).

• Hosting / Provider: Hugging Face Serverless Inference Router ("microsoft/biogpt").

• API Integration: Queries "router.huggingface.co/hf-inference/models/microsoft/biogpt" via HTTPS Bearer token authorization.

• Resilience & Fallback: To counteract enterprise BTP container egress restrictions (such as DNS "ENOTFOUND" errors), the Node backend features an automatic dual-router timeout fallback and an in-memory biomedical heuristic synthesizer, ensuring continuous uptime.

5. Backend Engineering, Pipeline & Data Processing

The Node.js/Express backend manages several core data-engineering workflows:

• **Spreadsheet Parsing (SheetJS/xlsx):** Uploaded datasets (.ods, .xlsx, .csv) are streamed into memory using Multer, parsed with SheetJS, and transformed into normalized JSON objects. Source row indices are mapped directly (e.g., Patient C -> Rows [4, 8, 46]) to provide complete dataset-to-patient traceability.

• **Real-Time Mathematical & Statistical Engine (simple-statistics):** The system dynamically computes healthy control benchmarks (mean and standard deviation) across normal cohort rows, executes multi-variable Pearson correlation matrices, and calculates Z-scores across all measured acoustic parameters to derive an objective Ear Health Score (0%–100%).

• **Relational Storage Layer (PostgreSQL/pg):** Structured patient records, timestamps, visit counts, alert flags, and audit events are stored in relational tables using parameterized SQL queries to prevent injection vulnerabilities.

• **Object Archiving (Azure Blob Storage):** Raw uploaded files are stored in an Azure Blob Storage container ("medical-data") for archival and regulatory compliance.

6. Document Generation Engines (PDF & Word)

To eliminate manual report compilation, two programmatic document generation pipelines run entirely on the server:

• **Programmatic PDF Generation (PDFKit):** This utilizes "pdfkit" to construct a single, multi-page consolidated cohort PDF streamed directly from memory to the client browser. It also features clean page pagination ("doc.addPage()"), vector hyperlinks to

external PubMed literature, table borders, custom Q&A query-answer callout blocks, and active clickable elements.

• **Programmatic Word Dossier Generation (docx):** This uses the "docx" library to construct structured Microsoft Word (.docx) files. It further incorporates a centralized Internationalization (I18N) dictionary supporting five languages: English (EN), German (DE), Spanish (ES), Italian (IT), and French (FR).

7. Frontend Client Architecture

The client interface is designed as an ultra-lightweight Single Page Application (SPA) that loads instantly without heavy frontend framework overhead:

- **Vanilla HTML5 / Modern CSS3:** Styled according to SAP Fiori enterprise guidelines (Fiori Navy Shell, SAP Blue accents, clean tabular data cards, and responsive sidebar controls).
- **Interactive Data Visualizations (Chart.js):** Renders dynamic analytical charts, including Jerger classification distribution donuts, health score histograms, age cohort distributions, and condition breakdowns.
- **State Management & Q&A Persistence:** Maintains client-side patient session states, with custom questions asked in the interactive AI prompt being stored in memory ("patientQnAMap") and packaged into the PDF export payload so they render in the downloaded documentation.

8. Technical Deliverables Summary

In summary, the project delivers a production-grade enterprise software architecture that combines the following:

• **SAP Enterprise Standards:** Native SAP BTP Cloud Foundry deployment with XSUAA OAuth2 security and Generative AI Hub integration.

• **Multi-Engine AI Triad:** Simultaneous benchmarking across OpenAI GPT-4o, Anthropic Claude 3.5 Sonnet, and Microsoft BioGPT.

• **Resilient Microservices:** Egress DNS error handling and in-memory fail-safe heuristic pipelines.

• **Full-Stack Traceability:** From raw spreadsheet rows to relational database records, AI inference summaries, and one-click PDF/Word exports.

Conclusion

Using a production-ready enterprise architecture, isolated data from the PLAI measurement is analyzed and presented using AI in a way that allows clinicians to receive a detailed summary of the results and analyses. Additionally, corrections can be made both during the course of a study and later in clinical use.

Declarations

Funding: A request for financial support is being submitted for this study.

Conflict of interest: All authors declare that they have no conflicts of interest.

Ethics approval: The study is being conducted in accordance with the Declaration of Helsinki.

Use of AI-assisted technologies: The authors utilized ChatGPT (OpenAI) for language editing, structural refinement, and drafting support. All AI-assisted content was reviewed, edited, and verified by the authors.

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