Applying Hidden Markov Models (HMMs) to Gastrointestinal Disease Risk Prediction

The goal of my capstone project is to develop a Clinical Decision Support System (CDSS) that predicts the risk and classifies lab results for **gastrointestinal (GI) diseases**, with a particular focus on **Helicobacter pylori**. This system aims to tackle the underdiagnosis and late detection of GI illnesses in Rwanda by learning from patient data collected over time.

Observations:
The HMM will use sequential patient data including symptom reports (e.g., nausea, abdominal pain, changes in appetite), lab results (e.g., urea breath tests, stool antigen tests, bloodwork), vital signs, and indicators of progression captured over multiple visits. These observations reflect the visible outcomes stemming from hidden disease stages such as infection, early ulceration, or chronic gastritis.

Type of HMM Problem:
Since the true disease stages are not directly observable, this is an unsupervised **HMM Learning Problem**. I will be trying to learn the model itself , train it with observation sequences, then figure out how the disease changes or gets worse over time by looking at patterns in the patient's medical test results and symptoms collected over several days or visits.

Training Algorithm & Parameter Estimation:

a) **Known values**
At the start, the known values include the number of hidden states (informed by medical domain knowledge e.g., three to five stages), initial model parameters (random, based on rough guesses or expert rules.), and the observation sequences.
b) **Unknown values** such as transition probabilities, emission probabilities, and the initial state distribution are learned during training via the **Baum–Welch algorithm** (an Expectation-Maximization technique) [1].
c) During this process, the HMM updates the transition matrix AAA, emission matrix BBB, and the initial state distribution pi [2], enabling it to learn how Gastro Intestinal conditions evolve and manifest through lab results.

References

[1] L. E. Baum and L. R. Welch, "A Statistical Approach to the Probabilistic Functions of Finite State Markov Chains," *IEEE Transactions on Information Theory*, vol. 15, no. 6, pp. 408–420, 1970. [Online]. Available: https://ieeexplore.ieee.org/document/1055030. DOI: 10.1109/TIT.1970.1055030

[2] L. R. Rabiner, "A Tutorial on Hidden Markov Models and Selected Applications in Speech Recognition," *Proceedings of the IEEE*, vol. 77, no. 2, pp. 257–286, 1989. [Online]. Available: https://ieeexplore.ieee.org/document/18626. DOI: 10.1109/5.18626