Applying Hidden Markov Models to Agrika: Predictive Maintenance

Capstone Idea Overview: Agrika enhances sustainable farming in Rwanda by predicting agricultural equipment failures for smallholder farmers. It analyzes equipment health to reduce downtime, using historical maintenance logs and manual data (future work includes IoT sensors for real-time data). The system provides SMS-based maintenance alerts, supporting Pay-As-You-Go mechanization and boosting productivity.

Observations: The HMM uses measurable data from equipment logs:

- **Vibration levels**: Frequency/amplitude, indicating wear.
- **Temperature**: Engine/component readings, signalling overheating.
- **Usage patterns**: Operating hours/cycles, reflecting stress.
- **Maintenance events**: Recorded repairs/downtime.
  These time-series data, aggregated daily or per cycle, model equipment health states.

Type of HMM Problem: Since hidden states (e.g., normal, degraded, critical) are unknown and must be inferred, this is an **unsupervised learning problem**. The HMM identifies health states from data patterns without predefined labels.

Training Algorithm:

- **a. Known Values at Start**:
  - **Observation sequence**: Vibration, temperature, usage, and maintenance data.
  - **Number of states**: Assumed (e.g., 3 states: normal, degraded, critical).
  - **Initial parameters**: Random/heuristic probabilities for transitions, emissions, and state distribution.
- **b. Unknown Values to be Learned**:
  - **Hidden states**: Specific health states (e.g., degraded, critical).
  - **Transition probabilities**: Likelihoods of state changes (e.g., normal to degraded).
  - **Emission probabilities**: Probabilities of observing data (e.g., high vibration) per state.
  - **Initial state distribution**: Starting probabilities for each state.

Parameter Updates: The **Baum-Welch algorithm** updates:

- **Transition matrix (A)**: Probabilities of moving between health states.
- **Emission matrix (B)**: Probabilities of observing data given a state.
- **Initial state distribution (π)**: Starting state probabilities.
  These updates maximise the likelihood of observed data, enabling failure prediction.

Future Work: IoT sensors will provide real-time data, improving HMM accuracy for precise health state modelling and timely alerts, further reducing downtime.