Disease degradation models for chronic digestive conditions

Vironix Problem Statement - Math Problems in Industry Workshop - 2026

Chronic gastrointestinal (GI) disorders - such as Irritable Bowel Syndrome (IBS), Inflammatory Bowel Disease (IBD: Crohn's/Ulcerative Colitis), Gastroesophageal Reflux Disease (GERD), and Celiac Disease - are long-term conditions affecting the digestive system. They are characterized by non-linear progression, where long periods of stability are interrupted by severe exacerbations, or “flares”.

Traditional first-principles models, such as multi-compartmental differential equations, excel at representing physiological mechanisms but often fail to capture the stochastic nature of real-world patient data. Conversely, statistical learning/machine learning (ML) models can process vast datasets to identify biomarkers or predict readmission risks but frequently lack mechanistic interpretability required for clinical trust and decision making.

Emerging research suggests that simple, non-invasive physiological metrics (weight, blood pressure (BP), and bowel movement (BM) frequency contain early-warning signals of clinical degradation.

Our goal here is to develop a hybrid "Disease Degradation Model" that integrates mechanistic foundations with statistical learning methods and clinical data. The model(s) are required to address two objectives:

a) Short term prediction - Identify active flares and forecast flare risk within a short timescale window (3 weeks - 1 year).

b) Mapping the long term progression of the chronic digestive disorder

Model inputs include patient biodata, longitudinal dataset of simple vitals and patient-reported symptoms, periodic tests, and treatment protocol information.

Team members are asked to address the following lines of enquiry during the workshop:

1. Literature Study: Identify and compare existing mechanistic models of the GI tract and ML-based diagnostic/prognostic models for IBD or IBS. How do their assumptions differ? What mechanistic details of the disease are available? What validation studies have been conducted for these models?

2. Formulate a set of models that describe a specific degradation process (e.g., the loss of intestinal barrier integrity or the depletion of short-chain fatty acids) and its response to a given treatment protocol.

3. Propose methods to assess model input parameters and couple model outputs to predict flares and long-term progression using patient longitudinal data. (e.g. use

ML model predict rate constants in a differential equation that models the patient disease state*)*

4. Identify which model parameters are most sensitive to patient-specific data. How can we validate the mechanistic plausibility of your hybrid model?

Some references to use as a starting point

1. Hypothesis: Mechanism of irritable bowel syndrome in inflammatory bowel disease, Yoshiharu Uno (https://doi.org/10.1016/j.mehy.2019.109324)
2. Physiological Data Collected From Wearable Devices Identify and Predict Inflammatory Bowel Disease Flares, Hirten et. al. (10.1053/j.gastro.2024.12.024)
3. Emerging wearable technology applications in gastroenterology: A review of the literature, Chong and Woo (10.3748/wjg.v27.i12.1149)
4. Machine Learning Prediction Model for Inflammatory Bowel Disease Based on Laboratory Markers. Working Model in a Discovery Cohort Study, Kraszewski et. al. (https://doi.org/10.3390/jcm10204745)