Forecasting Mentorship Fragility: A Gender-Aware Predictive Model of Drop-Off in OSS Communities

Introduction

Mentorship serves as a foundational pillar of contributor onboarding and retention in open-source software (OSS) communities. Contributors frequently rely on informal mentors to navigate technical challenges, social norms, and project-specific workflows. However, these mentorship relationships are often fragile and dissolve silently over time—especially in communities lacking formal structures to support them. While existing research has underscored the benefits of mentorship in OSS, few studies have investigated the early warning signs of mentorship decay, particularly through a computational lens. Even fewer have explored how gender dynamics may shape who receives sustained mentorship and who is left behind.

This study builds predictive models to detect the risk of mentorship "drop-off" — a gradual loss of mentor engagement — in OSS communities. Using large-scale GitHub interaction data, we examine the temporal and behavioral patterns of mentorship dyads, with gender modeled as a moderating variable. Our goal is to enable early interventions that prevent mentorship loss and address gendered asymmetries in support networks.

Methods

We constructed a longitudinal dataset from over 2,000 active GitHub repositories, selected to represent a range of technical domains, governance structures, and contributor bases. From these repositories, we extracted contributor interaction logs, focusing on activities that reflect mentorship-like behavior: frequent and asymmetric commenting, pull request (PR) review, code feedback, and issue resolution where one contributor (the mentor) engages repeatedly with another (the mentee) over time. Mentorship dyads were inferred by computing the directed density of interactions across a rolling 90-day window, excluding peer-to-peer interactions that were symmetric or transient.

Mentorship "drop-off" was defined as a cessation of these interaction patterns for at least 90 days, despite continued activity by the mentee. This definition isolates cases where a

mentor disengages but the mentee remains active, allowing us to distinguish mentor drop-off from overall contributor churn. We engineered over 40 features to capture social, behavioral, and contextual signals: interaction frequency and recency, latency of replies, semantic similarity between comments and PRs, contributor tenure, time zone overlap, and network centrality. Sentiment and civility scores of previous mentor-mentee interactions were also included using transformer-based sentiment models fine-tuned for OSS discourse.

Gender inference was conducted via an ensemble method using Genderize.io, Wikidata mappings, and profile-linked pronouns (when available), with strict thresholds for inclusion. Contributors with ambiguous or low-confidence gender labels were excluded from gender-based analyses. Gender was incorporated both as a binary variable and as part of interaction dyads (e.g., woman mentee–man mentor) to explore intersectional effects.

Three modeling approaches were used:
 (1) **Cox Proportional Hazards Models** to estimate the hazard of mentorship drop-off, with time-varying covariates;
 (2) **Gradient Boosting Machines (GBM)** to capture non-linear interactions and feature importance; and
 (3) **LSTM-based Recurrent Neural Networks** to model sequential interaction dynamics and decay signals.

Models were trained using time-aware stratified cross-validation and evaluated via C-index, AUC-PR, and calibration curves. SHAP values were used to interpret model behavior and identify predictive signals of mentorship fragility, including whether sentiment polarity shifts or delays in feedback predicted disengagement more acutely for women mentees.

Potential Impact

This study introduces a data-driven, gender-aware framework for anticipating mentorship breakdown in OSS. By integrating computational sociology, machine learning, and gender equity research, we provide tools for community organizers and maintainers to detect fragile mentorship ties and intervene before dropout occurs. Our models also surface hidden biases in mentorship sustainability, suggesting that contributors from marginalized genders may face higher drop-off risk despite comparable engagement. The work contributes both methodologically—by operationalizing informal mentorship in OSS—and practically, by equipping open-source communities with mechanisms for more equitable, supportive contributor ecosystems.