Research Statement : *Sandeep Kaur Kuttal*

My research advances human-centered software engineering by uncovering the behaviors of problem-solving professionals and inventing intelligent, inclusive solutions at the intersection of software engineering (SE), human-computer interaction (HCI), and artificial intelligence (AI). I study how diverse individuals—including professional software engineers, end-user programmers, novices, and those from historically underrepresented groups—engage in solo, team-based, and human–AI programming contexts, including remote and technology-mediated collaboration. Through a rigorous, iterative process grounded in empirical inquiry, theory-building, and systematic evaluation, I produce novel strategies, frameworks, algorithms, visualizations, and tools that bridge human intent with machine execution—expanding the boundaries of inclusive, experience-centered software engineering.

1. Research Leadership and Impact

My research has earned two prestigious early-career faculty awards: the **NSF CAREER Award** and the **AFOSR Young Investigator Program (YIP) Award**, totaling $1 million. Overall, I have secured $7.7 million in extramural and intramural funding. At the institutional level, I received the **Carla Savage Award**, awarded for outstanding research in the NC State Computer Science Department.

I have published 53 peer-reviewed papers in premier venues spanning SE, HCI, and AI, including *TOCHI, TOSEM, CHI, FSE*, and *ICSE–SEIS*. These publications are co-authored either by me as first author or by my student mentees, reflecting a sustained commitment to high-impact, collaborative scholarship. My work has received **Best Paper Awards** at *ACM CHI* and *ACM/IEEE ICGSE*, as well as an **Honorable Mention** at *ACM CHI*.

To advance and disseminate my research, I have delivered **five keynote presentations** at conferences and workshops, including an **ACM Tech Talk** *"Towards Seamless Collaboration: Redefining Human-AI Interaction in Programming."* I have also given **25 invited talks** to academic and industry audiences.

In parallel, I have established a strong record of **service and leadership** in the SE and HCI communities. I serve on the **editorial board** of *COLA*, the **steering committee for** *VL/HCC*, and the **program board member** for the Human-AI cluster at *HCII*. I am a member of the NC State College of Engineering **AI Advisory Team**. I have held numerous roles on **program committees** and **conference organizing teams** for premier conferences such as *CHI, VL/HCC, HCII,* and *ASE*. In 2025, I will serve as **General Chair** for *VL/HCC*, leading the planning and execution of the conference. I also organize workshops, chair tracks at top venues including *CHI, ICSE*, & review approximately **50 research papers** annually.

2. Research Overview

My research spans the following key areas:

2.1. Human-AI Pair Programming Agents

Conversational agents (CAs) are increasingly embedded in everyday life—powering virtual assistants like Siri, Alexa, and Google Assistant, as well as customer service bots across industries. Yet when I began this work, no such agents supported programming tasks, despite the inherently collaborative and communicative nature of software development. Motivated by this gap, I initiated foundational research on inclusive conversational agents for pair programming, securing an *NSF CAREER Award* to advance this vision. The project aims to strengthen research infrastructure by providing publicly available research datasets, end-to-end conversational agents, and educational resources for the academic community.

- **Designing Inclusive Pair Programming Agents [1-4]:** I led the development of PairBuddy, one of the first conversational agents explicitly designed for software development. This work was grounded in an extensive interdisciplinary literature review spanning HCI, human-robot interaction, AI,

education, psychology, cognitive science, and management. Drawing on insights from human-human pair programming studies and refined through Wizard-of-Oz experiments conducted with my students, I established 12 inclusive design guidelines spanning interface design, interaction strategies, and both technical and social competencies. Unlike traditional coding assistants, PairBuddy uniquely blends technical support (e.g., debugging, creativity scaffolds) with social intelligence (e.g., motivation, adaptability) to enhance collaboration and cognition. This work, published in *ACM Transactions on Computer-Human Interaction (TOCHI)* and presented at *CHI*, contributes a reusable framework for designing anthropomorphic developer agents.

- **Evaluating Human-AI Programming Collaboration [4,7]:** I conducted the first empirical study comparing human–human and human–agent pair programming, demonstrating that AI partners can match human collaborators in task support and enhance self-efficacy. My findings revealed novel interaction dynamics, including over-reliance on AI agents and gender-based differences in communication styles–raising critical questions about trust, delegation, and inclusion in human–AI collaboration. Co-authored with two undergraduate women mentees, this research received an *Honorable Mention* at *ACM CHI*, underscoring both its scholarly impact and my commitment to inclusive undergraduate research.
- **Advancing NLU for Developer Conversations [5-11]:** I led the development of one of the first natural language understanding (NLU) datasets tailored to software engineering, along with a 26-label taxonomy capturing the complexity of developer dialogue. To scale data collection, I also led a study with my students that leveraged YouTube vlogs and other sources to curate over 13,000 utterances—enabling more realistic training for pair programming agents. Our fine-tuned transformer models (BERT, GPT-2, XLNet) achieved 95% accuracy in role classification and reduced training needs fivefold. Published at venues such as ACM FSE and HCII, this work provides foundational datasets, annotation schemas, and modeling techniques for building inclusive, socially aware conversational systems in software development.

2.2. Collective Foraging Intelligence & Information Foraging Theory

Collaborative software development leverages collective intelligence but faces a critical challenge: efficiently navigating and synthesizing fragmented information, especially within remote and distributed teams that collaborate primarily through digital interfaces. This research leverages Information Foraging Theory (IFT) to model how developers–similar to animals foraging for food–seek, interpret, and act on information "scents" in complex environments such as IDEs, code repositories, and the web. Building on IFT, I have extended its application to five software engineering domains to reduce cognitive load and foster intelligent, inclusive development. The broader goal is to build foundational theory and infrastructure—including predictive models, behavioral datasets, and intelligent interfaces—to enable scalable, inclusive navigation of software knowledge. This research was recognized with the *Air Force Office of Scientific Research (AFOSR) Young Investigator Program (YIP) Award*.

- **Pioneering Extension of IFT to Software Engineering [12-25]:** My research has advanced and expanded IFT as a foundational framework for modeling developer behavior. Together with my students and collaborators, I applied IFT across diverse software engineering domains–including debugging, end-user programming, GitHub navigation, Stack Overflow Q&A, and web-based development–revealing new "information scent" cues and cognitive strategies. I extended this work using machine learning to predict developers' cost–value decisions and uncovered gender-based differences in foraging behavior. Published in venues such as *VL/HCC* and *IST*, this line of research broadens IFT's theoretical scope and informs the design of inclusive, intelligent software tools.
- **Variation Foraging Theory & PFIS-V Computational Model [26,27]:** To address the cognitive demands of navigating similar artifact variants, Together with collaborators, I developed Variation Foraging Theory–the first theoretical extension of IFT to variant-rich environments. This work was validated through an award-winning empirical study that received *Best Paper Award* at *CHI*. Building on these insights, our team designed PFIS-V, a predictive computational model that improves variant

selection accuracy by up to 25%, outperforming prior models. Published at *CHI*, this work advances automated developer assistance for faster, more accurate codebase foraging.

- **Team Foraging Theory & PFIS-VT Model for Collaborative Code Navigation [28, In Progress]:** I am leading research with my students to extend IFT–traditionally applied to solo developers–to collaborative software development. We introduced Team Foraging Theory, the first framework modeling how remote teams collectively navigate codebases, incorporating team communication dynamics as key foraging cues. Building on this, we are developing PFIS–Virtual Team (PFIS-VT), a predictive model that integrates social signals, evolving goals, and IDE activity to better anticipate team navigation than existing solo-based models. This ongoing work demonstrates how theory-driven insights can inform the design of intelligent, inclusive tools for distributed collaboration.
- **Advancing Cognitive and Social Models of Software Work [29, In Progress]**: I am currently leading research on how developers think, collaborate, and interact with tools. With my students, I am advancing projects including a graph-based simulation of code navigation, machine learning models of metacognition and social cognition in remote teams, and an EEG/EDA study on the impact of background music on cognitive load and collaboration in pair programming. These efforts drive a new paradigm for cognition-aware, inclusive developer tools.

2.3. Supporting Problem-Solving Professionals [30-45]

My research has advanced our understanding of how problem-solving professionals approach programming tasks. Based on findings from empirical studies, I have iteratively developed novel tools and methods to support their workflows:

- **Scaffolding End-User Problem Solving [30, 31]:** Co-designed with colleagues and grounded in Minimalist Learning Theory, I led the development of Idea Garden—an IDE embedding core problem-solving strategies with just-in-time, context-sensitive prompts for end-user programmers (EUPs). Studies showed it supported diverse cognitive strategies and empowered users to overcome programming barriers independently. This work was published at *VL/HCC*.
- **Visual Tools for Exploration and Skill Assessment [32-37]:** I introduced variation management across time and space to support exploratory programming, leading the development of tools such as AppInventorHelper and PipePlumber, which automatically organize and visualize program versions for EUPs. PipePlumber, published in *TOCHI* and presented at *CHI*, was among the first systems to help EUPs effectively manage evolving code variants. Additionally, my colleagues and I developed Visual Resume, which aggregates developer activity from GitHub and Stack Overflow to provide comprehensive assessments of technical and socio-technical skills-supporting hiring and mentoring decisions. This research received a *Best Paper Award* at *ICGSE*.
- **Debugging Support for Web Mashups[38]:** My research was the first to provide debugging support for web mashups by classifying intra- and inter-modular bugs in a visual programming environment. I developed a hybrid anomaly detector and a user-centered interface tailored to distributed mashup systems. By integrating static and dynamic analysis, this tool significantly improved end-user programmers' ability to detect and fix bugs. This work was published at *CHI*.

2.4. Inclusive Collaboration in Software Teams

The rise of remote and hybrid work has transformed software team collaboration, yet most platforms neglect the impact of social identities–such as gender and race–on team dynamics. By uncovering differences in problem-solving and collaboration linked to these identities, I design tools that better support diverse remote teams. Drawing from multiple disciplines–including SE, HCI, and organizational psychology–I lead research to provide a robust theoretical framework, empirical insights, and practical solutions to build inclusive, equitable team systems.

- **Social Identity in Remote Pair Programming Collaboration [46-51]:** I led the first empirical studies in software engineering–conducted with my students–that examined how gender and race

influence collaboration in remote pair programming. Our research revealed that mixed-gender pairs experienced more interruptions, unequal task delegation, and lower self-efficacy compared to same-gender pairs. These findings were published at *VL/HCC*. A follow-up study focusing on Black–White pairs revealed that mixed-race teams showed higher productivity and balanced leadership but faced greater communication anxiety. This study was published in the *TOSEM* and presented at *ICSE*. Together, these contributions provide a foundational understanding of the impact of social identity on developer collaboration.

- **Equity-Centered Research Methods [52,53]** To advance equity in empirical software engineering, I led the development—together with my student—of one of the first empirically grounded frameworks for recruiting and retaining diverse participants. Based on interviews with 20 researchers, our work identifies key structural and interpersonal barriers (e.g., mistrust, restrictive IRB policies), and offers field-tested strategies such as participant-centered protocols and inclusive recruitment materials. A novel identity-method matrix links participant identities (e.g., gender, race, disability) to tailored approaches, enabling more inclusive and context-sensitive study designs. Published in the *ICSE SEIS* track, this work sets a new standard for conducting ethical, equity-centered research in computing.
- **From Insight to Action:** I identified key inclusivity barriers in remote collaboration via the 3Cs framework–Communication, Coordination, & Collaboration–which informed three interventions:
  - **RemoteCollabEval: Identifying "Inclusivity Bugs" in Collaborative Tools [In Progress]:** I am leading the development of RemoteCollabEval, a structured evaluation framework designed for industry to detect inclusivity bugs in their collaboration products. This method, which can also be integrated into classroom instruction. Adapted from GenderMag and Groupware Walkthroughs, it uses scenario-based personas to assess key facets of inclusive teamwork. Early empirical studies demonstrate its effectiveness in uncovering design flaws that hinder equitable collaboration.
  - **PairEquity: A Real-Time Facilitator for Inclusive Programming [In Progress]:** I am leading the development of PairEquity, an AI-powered facilitator that uses multimodal data–keystrokes, speech, and facial expressions–to detect interaction imbalances and provide real-time, research-backed feedback. PairEquity is designed both for industry use to enhance team collaboration and as a tool to support students learning inclusive programming practices.
  - **Pedagogical Innovation: Embedding the 3Cs Framework into SE Education [In Progress]:** I led efforts to integrate the 3Cs framework into software engineering curricula, helping students recognize and navigate equity challenges in team settings. This approach is currently being piloted and evaluated in classroom contexts to guide future inclusive curriculum design.

3. Mentorship and Collaboration

I lead the **Human Factors + Experience Engineering** (HFXE) group. Guided by our group's motto—*"Discovering and Inventing for Human-Centered SE and AI"*—we develop inclusive, intelligent tools that bridge human intention and machine execution. I currently advise four Ph.D. students and one M.S. student, several of whom have co-authored peer-reviewed publications and delivered research presentations.Ph.D. student Shandler Mason has co-authored eight papers and earned awards like the Carla Savage and From Theory to Nia Awards for her research and leadership. Among M.S. alumni, Peter Robe co-authored four papers in top venues (FSE, CHI, TOCHI, VL/HCC), and Abim Sedhain co-authored eleven publications. Over 50 undergraduates have participated in HFXE through REUs, internships, and independent studies; 25 have co-authored peer-reviewed publications, including one that received an Honorable Mention at ACM CHI, co-authored by two undergraduate women. To broaden student experience and deepen research impact, my lab has engaged in collaborations with researchers at IBM TJ Watson Research Center (David Piorkowski, Rachel Bellamy, Yunfeng Zhang), Microsoft Research (Sruti Ragavan, now faculty at IIT Kanpur), and academic partners at Oregon State University (Prasad Tadepalli), the University of Tulsa (Brett McKinney), the University of Tartu (Rajesh Sharma, Ezequiel Scott), and the University of Maryland (Snehesh Shrestha). These partnerships have supported student-led research in intelligent code navigation, natural language processing, and inclusive AI tools.

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