

# Carel van Niekerk

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## Summary

Research Scientist / Engineer specialising in **Reinforcement Learning (RL)** Post-training and **Large Language Models Alignment**. Expert in developing methods for **model trustworthiness, uncertainty quantification, and hallucination reduction**. Proven ability to bridge **rigorous** mathematical theory and production-level **engineering** by designing **scalable, reliable** and **modular** training frameworks. Extensive publication record at **NeurIPS, ACL, and EMNLP**, with a focus on delivering **creative**, high-impact solutions to complex research challenges.

## Skills

<b>Research</b>	Reinforcement Learning (Reinforcement Learning from Human/Intrinsic Feedback), Uncertainty Quantification, Self-supervised Learning, LLM Evaluation & Benchmarking, Human-in-the-loop, Model Debugging, Distribution Theory.
<b>Deep Learning</b>	PyTorch, Hugging Face Ecosystem (Transformers, TRL, Accelerate, Datasets)
<b>Agentic Systems</b>	LangGraph, DeepEval.
<b>Programming</b>	Python (Advanced), C++, Rust, MyPy/Ty (Type Checking in Python).
<b>Infrastructure</b>	Distributed Training (DeepSpeed, Accelerate), HPC Scheduling (SLURM), Cloud Orchestration (SkyPilot), Hydra (Configuration Management).
<b>Engineering</b>	Software Engineering and Design Patterns, Testing and Formatting (PyTest, Ruff), Debugging (pdb/VSCode), API Development (FastAPI, Pydantic).
<b>Core Languages</b>	Technical Leadership & Mentorship, Technical Writing, Collaboration, Mathematical Statistics, Linear Algebra & Calculus. English (Native), Afrikaans (Native), German (Fluent).

## Experience

### Postdoctoral Researcher

HEINRICH HEINE UNIVERSITY

March 2024 – Present

Düsseldorf, Germany

- Agentic Multi-Agent Reinforcement Learning:** Led the development of a MARL framework for telephonic dialogue systems, enabling coordinated decision-making between router and expert agents with explicit credit assignment. This approach improved routing accuracy by **over 15 percentage points** in a production-level dialogue product.
- HydraXcel:** Sole developer and maintainer of an open-source, configuration-driven deep learning experiment launcher. Integrated Facebook Hydra, Hugging Face Accelerate, and the UV workflow to support **scalable multi-GPU and distributed training**. The framework enables seamless, scalable **multi-GPU and distributed training** for the research team.
- HPC & Cloud Training Infrastructure:** Designed and implemented Hydra launcher plugins enabling transparent execution of experiments on SLURM-managed HPC clusters and via **SkyPilot** on cloud platforms. This infrastructure enabled high-throughput experimentation and rapid switching between compute backends without code changes.
- Academic Leadership:** Supervised multiple Master's theses focused on MARL and task-oriented dialogue. Designed and instructed the “Implementing Transformers” course, guiding students through building the *Attention Is All You Need* architecture from first principles in **PyTorch**, with emphasis on attention mechanics, training dynamics, and debugging. Achieved a 95% course pass rate.

### PhD Candidate

HEINRICH HEINE UNIVERSITY

Jul 2019 – Mar 2024

Düsseldorf, Germany

- Uncertainty-Aware Decision Making:** Developed computationally efficient methods for uncertainty quantification in intent classification in collaboration with Yandex Research. Integrated uncertainty features into reinforcement learning policies, improving real-user interaction success by **5 percentage points**. Designed an **Active Learning** strategy that achieved full-dataset performance using only **16% of expert annotations**.
- ConvLab-3 Dialogue Systems Toolkit:** Core developer of a large-scale dialogue system toolkit in collaboration with Tsinghua University and Microsoft Research. Architected a unified data format enabling seamless integration of heterogeneous datasets and models, significantly reducing engineering overhead for generalisation and reinforcement learning research. The toolkit has been adopted in **30+ research papers** spanning RL- and LLM-based dialogue agents.
- Young Researchers Roundtable on Spoken Dialogue Systems (YRRSDS):** Co-organised the 2022 edition collocated with **SIGDIAL** in Edinburgh. Managed the digital infrastructure and branding for the workshop and contributed to **sponsorship acquisition**.

### Artificial Intelligence Applications Consultant

NGA RISKSECURE

Jun 2018 – May 2019

Pretoria, South Africa

- Named Entity Sentiment Analysis:** Co-developed a sentiment scoring system for news-based entities, delivering reliable quantitative metrics to banking clients at **under 70% of the cost** of manual analysis.
- Multimodal Computer Vision Systems:** Developed a proof-of-concept application combining visual and sensor data to monitor greenhouse plant health for a CBD producer in Southern Africa.

# Selected Publications

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<b>Post-Training Large Language Models via Reinforcement Learning from Self-Feedback</b>	Jul 2025
CAREL VAN NIEKERK, RENATO VUKOVIC, BENJAMIN MATTHIAS RUPPIK, ET AL.	Under revision at EACL
<ul style="list-style-type: none"><li>Developed Reinforcement Learning from Self-Feedback (RLSF), a novel <b>post-training technique</b> utilising <b>intrinsic model confidence</b> to reduce reliance on external human preference data.</li><li>Demonstrated that RL based on intrinsic feedback is a <b>data-efficient alternative for the LLM post-training pipeline</b>, reaching beam-search performance with single-trace decoding.</li></ul>	
<b>Less is More: Local Intrinsic Dimensions of Contextual Language Models</b>	Oct 2025
BENJAMIN MATTHIAS RUPPIK, JULIUS VON ROHRSCHEIDT, CAREL VAN NIEKERK, MICHAEL HECK, ET AL.	NeurIPS 2025
<ul style="list-style-type: none"><li>Identified that Local Intrinsic Dimensions (LID) provide <b>critical insights into model training dynamics</b> and generalisation ability.</li><li>Proved that mean LID serves as a predictive metric for training capability exhaustion, <b>overfitting</b> in classification tasks, and the emergence of "grokking" in arithmetic tasks.</li></ul>	

## Education

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<b>PhD in Computer Science</b>	Jul 2019 – Mar 2024
HEINRICH HEINE UNIVERSITY	Düsseldorf, Germany
<b>Focus:</b> <i>Uncertainty Estimation, Management, and Utilisation in Human-Computer Dialogue</i>	
<b>MSc in Mathematical Statistics</b>	Jan 2017 – Nov 2018
UNIVERSITY OF PRETORIA	Pretoria, South Africa
<b>Relevant Modules:</b> <i>Statistical Learning, Data Analytics and Visualization, Mini-Dissertation</i>	
<b>BSc (Hons) in Mathematical Statistics</b>	Jan 2016 – Nov 2016
UNIVERSITY OF PRETORIA	Pretoria, South Africa
<b>Relevant Modules:</b> <i>Linear Models, Process Control, Research Report</i>	
<b>BSc in Actuarial and Financial Mathematics</b>	Jan 2013 – Nov 2015
UNIVERSITY OF PRETORIA	Pretoria, South Africa
<b>Relevant Modules:</b> <i>Mathematical Statistics, Imperative Programming, Linear Algebra, Calculus</i>	

## Research Themes

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<b>Alignment-Oriented Post-Training</b>	Reinforcement learning methods for aligning large language models using intrinsic and self-supervised reward signals, reducing reliance on external human preference data.
<b>Agentic and Tool-Augmented Systems</b>	Reinforcement learning and multi-agent coordination for long-horizon decision making in agentic dialogue and tool-using systems.
<b>Uncertainty-Aware Reasoning</b>	Bayesian and distributional methods for uncertainty estimation, calibration, and robustness, with applications to trustworthy and controllable AI systems.
<b>Scalable Research Infrastructure</b>	Design of reproducible, configurable, and distributed training systems enabling rapid experimentation across HPC and cloud environments.