University of Sheffield

Multi-Agent Framework for Email Generation: From Pre-trained Models to DPO Fine-tuning

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Declaration

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Abstract

One or two sentences providing a basic introduction to the field, comprehensible to a scientist in any discipline. Two to three sentences of more detailed background, comprehensible to scientists in related disciplines. One sentence clearly stating the general problem being addressed by this particular study. One sentence summarising the main result (with the words "here I show" or their equivalent). Two or three sentences explaining what the main result reveals in direct comparison to what was thought to be the case previously, or how the main result adds to previous knowledge. One or two sentences to put the results into a more general context. Two or three sentences to provide a broader perspective, readily comprehensible to a scientist in any discipline.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

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Chapter 2

Literature Review

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Chapter 3

Methodology

This chapter presents the methodology employed in this research to evaluate the effectiveness of language models in automated email generation through a novel multi-agent AI system. The methodology is structured in three stages: Stage 1 (System Design and Setup) establishes the foundational framework, Stage 2 (Experimental Implementation) details the execution procedures, and Stage 3 (Enhancement and Analysis) describes the analytical approach and planned extensions including Direct Preference Optimization fine-tuning.

3.1 Research Design and Approach

This study adopts a quantitative comparative research paradigm to systematically evaluate the performance of different language models in automated email generation tasks. The research is grounded in experimental design principles with controlled variables and systematic evaluation procedures to ensure methodological rigor and reproducible results.

The central research problem addresses the effectiveness of various language model architectures and sizes in generating high-quality fundraising emails within a structured evaluation framework. This investigation is motivated by the growing need for automated content generation systems that can produce contextually appropriate and persuasive communication while maintaining consistency and quality across different model implementations.

The methodological approach employs a multi-agent system design as a novel contribution to the field of automated text generation evaluation. Unlike traditional single-model assessment approaches, this methodology introduces specialist agents for distinct phases of the evaluation process, enabling more comprehensive and systematic comparison of model capabilities. The multi-agent approach provides several advantages over conventional evaluation methods: enhanced objectivity through agent specialization, systematic evaluation criteria generation, and standardized assessment protocols across all tested models.

Figure 3.1: *Overview of the research design and multi-agent evaluation framework*

The research questions guiding this investigation focus on comparative performance assessment across different model categories, consistency of output quality within individual models, and the effectiveness of the proposed multi-agent evaluation framework in providing reliable and valid assessments of generated content quality.

3.2 System Architecture Overview

The proposed system implements a three-agent architecture designed to systematically evaluate language model performance in email generation tasks. Each agent serves a distinct function within the evaluation pipeline, ensuring comprehensive assessment while maintaining methodological consistency across all experimental conditions.

The **Email Generator Agent** serves as the primary content creation component, responsible for generating fundraising emails based on standardized prompts and topic specifications. This agent interfaces with multiple language models sequentially, ensuring consistent input conditions while capturing the unique characteristics and capabilities of each model under evaluation.

The **Checklist Creator Agent** functions as the evaluation criteria development component, generating structured assessment frameworks for each generated email. This agent produces binary evaluation checklists with priority weighting, ensuring that assessment criteria are both comprehensive and relevant to the specific content and context of each generated email. The checklist generation process maintains consistency in evaluation standards while adapting to the nuanced characteristics of different email content.

The **Judge Agent** operates as the performance assessment and ranking component, applying the generated checklists to evaluate email quality systematically. This agent implements a probability-based scoring methodology that accounts for both binary assessment outcomes and priority weighting, providing quantitative measures for comparative analysis across different models and topics.

Figure 3.2: *Three-agent system architecture showing agent interactions and data flow*

The multi-model orchestration strategy enables parallel processing of different language models while maintaining experimental control and consistency. This approach maximizes computational efficiency while ensuring that each model receives identical input conditions and evaluation procedures, thereby supporting valid comparative analysis across the full range of tested models.

3.3 Model Selection and Categorization

The model selection process follows a systematic taxonomy based on parameter count and architectural characteristics, ensuring representative coverage across the spectrum of available open-source language models. This categorization enables meaningful comparison both within and across model size categories while accounting for the diverse capabilities and computational requirements of different model architectures.

3.3.1 Model Taxonomy and Categories

Models are categorized into three primary groups based on parameter count and intended use cases:

Small Models (1.1B-1.6B parameters) focus on resource efficiency and rapid inference capabilities. These models represent the lower bound of contemporary language model capabilities while offering practical advantages in computational requirements and deployment feasibility. The inclusion of small models enables assessment of whether compact architectures can achieve acceptable performance in structured email generation tasks.

Medium Models (7B-8B parameters) represent a balance between performance capabilities and computational efficiency. This category encompasses models that demonstrate

substantial language understanding and generation capabilities while remaining accessible for practical deployment scenarios. Medium models serve as the primary comparison baseline, representing the current mainstream approach to language model deployment.

Large Models (34B-70B parameters) provide assessment of maximum capability within the current open-source model landscape. These models enable evaluation of whether increased parameter count translates to proportional improvements in email generation quality and consistency, while establishing upper bounds for performance expectations within the experimental framework.

Table 3.1: *Language model specifications and categorization*

Model Name	Parameters	Category	Architecture
[Model specifications table to be completed]			

3.3.2 Selection Criteria and Rationale

The model selection process prioritizes open-source implementations to ensure reproducibility and accessibility of the research findings. Selection criteria include architectural diversity to capture different approaches to language modeling, availability of appropriate quantization options for efficient deployment, and demonstrated performance in text generation tasks based on existing literature and benchmarks.

Diversity considerations encompass different transformer architectures, training methodologies, and fine-tuning approaches represented across the selected models. This diversity ensures that the evaluation captures fundamental differences in model design and training rather than minor variations within a single architectural family.

3.4 Dataset and Topic Selection

The selection of charity fundraising emails as the evaluation domain provides several methodological advantages: clear assessment criteria for persuasive and contextually appropriate content, well-defined audience expectations and communication goals, and sufficient complexity to differentiate between model capabilities while remaining accessible for systematic evaluation.

3.4.1 Topic Development and Validation

The experimental dataset comprises 25 distinct fundraising topics distributed across 12 charity categories, providing comprehensive coverage of the fundraising domain while ensuring sufficient sample size for statistical analysis. Topic development follows a systematic process beginning with charity sector analysis and stakeholder consultation to identify representative fundraising scenarios.

The 12 charity categories include healthcare and medical research, education and youth development, environmental conservation, humanitarian aid and disaster relief, animal welfare, poverty alleviation and social services, elderly care and support, community development, disability support and accessibility, mental health awareness, refugee assistance, and

emergency medical services. This categorization ensures coverage of major charitable sectors while providing sufficient topic diversity for robust model evaluation.

Table 3.2: *Distribution of fundraising topics across charity categories*

Category	Topic Count	Examples
[Topic distribution table to be completed]		

3.4.2   Content Validation and Standardization

Topic standardization procedures ensure consistency in complexity, scope, and evaluation criteria across all experimental conditions. Each topic undergoes validation through expert review processes involving fundraising professionals and communication specialists to verify authenticity and appropriateness of the fundraising scenarios.

Content validation addresses both factual accuracy and representativeness of real-world fundraising communications. The validation process includes review of topic descriptions for clarity and specificity, assessment of fundraising goal appropriateness and realism, evaluation of target audience definition and communication objectives, and verification of ethical considerations and sensitivity requirements.

Ethical considerations in domain selection include ensuring respectful representation of charitable causes, avoiding exploitation of sensitive social issues for research purposes, and maintaining awareness of the potential impact of generated content on public perception of charitable organizations and causes.

The standardized topic framework provides consistent input conditions for all models while allowing sufficient variation to assess adaptability and contextual understanding across different fundraising scenarios. This approach supports both within-model consistency analysis and cross-model comparative evaluation within a controlled experimental environment.

3.5   Experimental Design

The experimental design implements a multi-topic comparative framework specifically developed to assess language model performance across diverse fundraising contexts while maintaining rigorous control over experimental variables. This design enables systematic comparison of model capabilities both within individual model categories and across the full spectrum of tested architectures.

3.5.1   Multi-Topic Comparative Framework

The comparative framework employs a factorial design approach where each model generates content for every topic within the experimental dataset, creating a comprehensive matrix of model-topic combinations for analysis. This approach ensures that performance assessments capture both model-specific capabilities and topic-dependent variations in generation quality.

Controlled variables within the experimental design include prompt standardization across all model-topic combinations, consistent input formatting and parameter specifications, uniform evaluation criteria application regardless of generating model, and standardized envi-

ronmental conditions for model inference. These controls ensure that observed performance differences reflect genuine model capabilities rather than experimental artifacts.

Randomization procedures minimize potential bias through several mechanisms: random ordering of topic presentation to each model prevents sequential effects, randomized model evaluation order eliminates potential carry-over effects, and random sampling of evaluation criteria prioritization reduces systematic bias in assessment frameworks.

3.5.2 Consistency Sampling Methodology

A critical innovation in this research is the implementation of consistency sampling through multiple generation approach, where each model generates three independent responses for every topic. This methodology enables assessment of both average performance and consistency reliability across repeated generations, providing insights into model stability and predictability.

The triple-generation approach serves multiple analytical purposes: quantification of within-model variance across identical input conditions, identification of models with high consistency versus those with variable output quality, assessment of optimal generation strategies for practical deployment scenarios, and establishment of confidence intervals for performance measurements.

Figure 3.3: *Experimental design workflow showing multi-topic comparative framework and consistency sampling*

Cross-validation strategies enhance reliability assessment through systematic rotation of evaluation procedures and independent validation of assessment criteria across different model-topic combinations. This approach ensures that evaluation frameworks maintain validity across the diverse range of content generated throughout the experimental process.

3.6 Evaluation Framework

The evaluation framework implements a novel multi-stage assessment methodology designed to provide comprehensive and objective analysis of generated email quality. This framework combines automated evaluation procedures with systematic criteria development to ensure consistent and reliable performance measurement across all experimental conditions.

3.6.1 Binary Checklist Generation Methodology

The checklist generation methodology employs the Checklist Creator Agent to develop structured evaluation frameworks tailored to each generated email while maintaining consistency in assessment standards. Each checklist comprises binary evaluation criteria that address key aspects of email effectiveness: content relevance and accuracy, persuasive appeal and emotional engagement, structural coherence and organization, audience appropriateness and tone, and call-to-action clarity and effectiveness.

The binary nature of evaluation criteria eliminates subjective scoring ambiguity while enabling systematic aggregation of assessment results across multiple evaluation dimensions.

Each criterion receives binary classification (pass/fail) with associated priority weighting to reflect relative importance within the overall assessment framework.

Priority weighting system development accounts for the varying significance of different evaluation criteria within fundraising email effectiveness. High-priority criteria include factual accuracy, ethical appropriateness, and clear charitable mission alignment. Medium-priority criteria encompass persuasive effectiveness, emotional appeal, and structural organization. Low-priority criteria address stylistic preferences and minor formatting considerations.

3.6.2 Judge Agent Evaluation Protocol

The Judge Agent implements a systematic evaluation protocol that applies generated checklists consistently across all email samples while accounting for priority weighting in final scoring calculations. The evaluation process follows a standardized sequence: comprehensive checklist application with binary assessment for each criterion, priority-weighted scoring aggregation to produce overall quality measures, comparative ranking generation across model outputs for identical topics, and consistency analysis across multiple generations from the same model.

The probability-based scoring methodology converts binary assessments into quantitative measures suitable for statistical analysis. The scoring algorithm weights individual criteria according to established priority levels and aggregates results to produce normalized performance scores ranging from 0 to 100 for comparative analysis purposes.

Table 3.3: *Evaluation criteria categories and priority weighting structure*

Category	Criteria	Priority	Weight
[Evaluation criteria table to be completed]			

Inter-model comparison metrics enable systematic assessment of relative performance across different model architectures and sizes. These metrics include absolute performance scores for individual model-topic combinations, relative ranking positions within topic-specific comparisons, consistency measures reflecting variance across multiple generations, and categorical performance analysis across small, medium, and large model groups.

3.7 Quality Assurance and Reliability

Quality assurance procedures ensure the integrity and reliability of experimental results through comprehensive validation mechanisms applied throughout the data collection and analysis processes. These procedures address potential sources of error, bias, and inconsistency that could compromise the validity of research findings.

3.7.1 Consistency Measurement and Validation

Consistency measurement across multiple generations provides crucial insights into model reliability and predictability. The measurement framework quantifies variation through statistical analysis of performance differences across the three generations per model-topic combination. Consistency metrics include standard deviation of performance scores across gener-

ations, coefficient of variation to normalize consistency measures across different performance levels, and range analysis to identify maximum performance variation within model outputs.

Output validation mechanisms verify the structural and content integrity of generated emails through automated checking procedures. Validation criteria include proper email formatting compliance, content length within specified parameters, topic relevance verification through keyword analysis, and ethical content screening to ensure appropriate charitable representation.

Bias identification and mitigation strategies address potential systematic influences on experimental results. Bias assessment includes analysis of model-specific performance patterns that might reflect training data characteristics, evaluation criteria bias that might favor particular model architectures or approaches, and temporal bias from sequential processing that might influence generation quality.

3.7.2 Reproducibility and Documentation Standards

Reproducibility measures ensure that experimental procedures can be replicated by independent researchers with access to the same models and datasets. Documentation standards include comprehensive recording of model configurations and parameters, detailed prompt specifications and input formatting procedures, complete evaluation criteria definitions and weighting schemes, and statistical analysis procedures with software version specifications.

Data integrity verification protocols monitor the experimental process to identify and correct potential data collection errors. Verification procedures include automated checking of complete data collection across all model-topic combinations, validation of evaluation scoring calculations and aggregation procedures, and cross-reference verification between generated content and corresponding evaluation results.

Figure 3.4: *Quality assurance and reliability verification workflow*

3.8 Data Collection Procedures

Data collection procedures implement a systematic pipeline designed to ensure comprehensive and consistent gathering of experimental data across all model-topic combinations while maintaining quality standards and enabling efficient analysis of results.

3.8.1 Systematic Generation Pipeline

The generation pipeline orchestrates the sequential application of all models to every topic within the experimental dataset, ensuring consistent conditions and comprehensive coverage of all required model-topic combinations. Pipeline implementation includes automated model loading and configuration management, standardized prompt application with consistent formatting across all models, systematic generation scheduling to optimize computational resource utilization, and automated storage of generated content with appropriate metadata and identification.

The pipeline incorporates error handling and recovery mechanisms to address potential model failures or generation issues without compromising experimental integrity. Recovery

procedures include automatic retry mechanisms for failed generations, alternative generation strategies for models with specific configuration requirements, and comprehensive logging of any issues encountered during the generation process.

3.8.2 Automated Evaluation and Scoring

Automated evaluation procedures apply the three-agent assessment framework systematically across all generated content, ensuring consistent evaluation standards while minimizing manual intervention requirements. The automated scoring system includes sequential application of checklist generation and evaluation procedures, standardized scoring calculations with priority weighting, and systematic aggregation of results across multiple generations per model-topic combination.

Cross-model performance measurement protocols enable fair comparison across diverse model architectures and capabilities. Measurement standardization includes normalized scoring procedures that account for different model output characteristics, consistent evaluation timeframes to ensure equal assessment opportunity for all models, and systematic application of identical evaluation criteria regardless of generating model.

Result aggregation and storage methodology organizes experimental data for efficient analysis while preserving complete information for detailed investigation and validation. Storage procedures include structured database organization with comprehensive metadata, automated backup and version control for data integrity, and export capabilities for statistical analysis software compatibility.

Table 3.4: *Data collection metrics and completeness verification*

Collection Phase	Expected Items	Collected Items	Success Rate
[Data collection metrics table to be completed]			

Statistical analysis preparation procedures ensure that collected data meets the requirements for planned analytical approaches while identifying any data quality issues that might affect subsequent analysis. Preparation includes verification of complete data collection across all experimental conditions, assessment of data distribution characteristics for appropriate statistical test selection, and identification of outliers or anomalous results requiring further investigation.

3.9 Direct Preference Optimization Extension

The methodology includes a planned extension incorporating Direct Preference Optimization (DPO) fine-tuning to enhance model performance based on comparative evaluation results from the initial experimental phase. This extension represents a significant methodological advancement that leverages the multi-agent evaluation framework to create preference-based training data for targeted model improvement.

3.9.1 DPO Methodology Framework

Direct Preference Optimization provides a theoretically grounded approach to fine-tuning language models using preference data derived from comparative evaluations. Unlike traditional

reinforcement learning from human feedback (RLHF) approaches, DPO directly optimizes the policy model using preference pairs without requiring a separate reward model, offering computational efficiency and training stability advantages.

The DPO methodology framework implemented in this research utilizes the comparative evaluation results generated by the Judge Agent to create structured preference pairs. Each preference pair consists of two email generations for the same topic, where one generation demonstrates superior performance according to the established evaluation criteria. This approach ensures that preference data directly reflects the quality distinctions identified through the systematic evaluation framework.

Training data preparation follows a systematic process that begins with the analysis of comparative evaluation results to identify consistent performance patterns across model-topic combinations. High-performing generations serve as preferred examples, while lower-performing generations from the same topic provide non-preferred comparisons. This methodology ensures that preference pairs capture meaningful quality differences while maintaining topic consistency.

3.9.2 Fine-tuning Experimental Design

The fine-tuning experimental design implements a controlled approach that enables systematic assessment of DPO effectiveness across different model categories. The design incorporates baseline preservation through comprehensive documentation of pre-fine-tuning performance characteristics, controlled fine-tuning procedures with standardized hyperparameters and training protocols, and systematic post-fine-tuning evaluation using identical assessment frameworks applied in the initial experimental phase.

Model selection for fine-tuning prioritizes medium-sized models (7B-8B parameters) that demonstrate adequate performance in initial evaluations while remaining computationally feasible for fine-tuning procedures. This approach enables meaningful assessment of fine-tuning effectiveness without excessive computational requirements while providing results applicable to practical deployment scenarios.

Preference data curation implements quality controls to ensure that training examples reflect genuine performance improvements rather than evaluation artifacts. Curation procedures include minimum performance threshold requirements for preferred examples, verification of substantial quality differences between preferred and non-preferred pairs, and topic distribution balancing to prevent over-representation of specific charitable categories.

Figure 3.5: *Direct Preference Optimization methodology workflow showing preference data creation and fine-tuning process*

3.9.3 Post-Fine-tuning Evaluation Protocol

Post-fine-tuning evaluation employs identical assessment procedures used in the initial experimental phase to ensure valid comparison of pre- and post-fine-tuning performance. The evaluation protocol maintains consistency in topic selection, prompt formatting, generation parameters, and assessment criteria application while documenting any observed changes in generation characteristics or evaluation outcomes.

Comparative analysis framework enables systematic assessment of fine-tuning effectiveness through multiple evaluation dimensions: absolute performance improvement measurement across all evaluation criteria, relative performance changes within specific charitable categories, consistency improvement assessment through variance analysis across multiple generations, and efficiency analysis comparing pre- and post-fine-tuning inference characteristics.

3.10 Performance Analysis Methods

The performance analysis methodology employs comprehensive statistical approaches designed to extract meaningful insights from the multi-dimensional experimental data while accounting for the complex relationships between model characteristics, topic variations, and evaluation outcomes.

3.10.1 Statistical Analysis Framework

The statistical analysis framework implements a multi-layered approach that addresses different aspects of model performance assessment through appropriate analytical techniques. Primary analysis focuses on comparative performance assessment across model categories using analysis of variance (ANOVA) procedures to identify significant differences between small, medium, and large model groups while controlling for topic-specific variations.

Significance testing methodology incorporates multiple comparison corrections to address the increased Type I error risk associated with numerous model-topic comparisons. Bonferroni correction procedures ensure that family-wise error rates remain within acceptable bounds while maintaining sufficient statistical power for meaningful effect detection. Effect size calculations using Cohen's d and eta-squared measures provide practical significance assessment beyond statistical significance testing.

Multi-dimensional performance assessment recognizes that email generation quality encompasses multiple evaluation criteria with varying importance levels. The analysis employs multivariate analysis of variance (MANOVA) procedures to assess simultaneous differences across multiple evaluation dimensions while preserving the relationships between different quality aspects.

Table 3.5: *Statistical analysis plan with testing procedures and significance criteria*

Analysis Type	Method	Purpose	Significance Level
[Statistical analysis plan table to be completed]			

3.10.2 Correlation and Trend Analysis

Correlation analysis investigates relationships between model characteristics and performance outcomes to identify systematic patterns that might inform model selection and deployment decisions. The analysis examines correlations between parameter count and overall performance scores, architectural features and specific evaluation criteria performance, and consistency measures and model reliability characteristics.

Trend identification across model categories employs regression analysis techniques to quantify performance scaling relationships and identify optimal model size categories for different deployment scenarios. Polynomial regression models assess non-linear relationships between model size and performance while accounting for diminishing returns that might occur with increasing parameter counts.

Temporal stability analysis examines performance consistency across the multiple generations per model-topic combination to assess model reliability and predictability. Variance component analysis quantifies the relative contributions of model-specific, topic-specific, and random variation sources to overall performance variation, informing model selection criteria for practical applications.

3.11   Result Validation and Interpretation

Result validation procedures ensure the reliability and generalizability of research findings through comprehensive verification mechanisms that address potential sources of bias, error, and misinterpretation while establishing confidence in the research conclusions.

3.11.1   External Validation Procedures

External validation employs independent assessment mechanisms to verify the reliability of the automated evaluation framework and validate the meaningfulness of identified performance differences. Expert evaluation integration involves fundraising professionals and communication specialists in reviewing selected email samples to assess whether automated evaluation outcomes align with human judgment regarding email quality and effectiveness.

The expert evaluation protocol implements a structured approach that parallels the automated assessment framework while allowing for nuanced human judgment. Expert evaluators assess the same email samples evaluated by the Judge Agent using comparable criteria but with the flexibility to provide qualitative feedback and identify aspects of quality that might not be captured through automated assessment procedures.

Human baseline comparison methodology establishes performance benchmarks through human-generated email samples for the same topics used in model evaluation. This comparison enables assessment of whether language model performance approaches or exceeds human-level quality in fundraising email generation while identifying specific areas where models demonstrate particular strengths or limitations.

Figure 3.6: *Multi-layer validation framework showing expert evaluation, human baseline comparison, and cross-validation procedures*

3.11.2   Interpretation Framework and Limitations

The result interpretation framework provides systematic guidelines for drawing valid conclusions from experimental data while acknowledging inherent limitations and potential alternative explanations for observed outcomes. Interpretation procedures include assessment of practical significance beyond statistical significance, consideration of confidence intervals and

effect size magnitudes, evaluation of result consistency across different analytical approaches, and identification of potential confounding variables or alternative explanations.

Limitation identification addresses several key areas that might affect result generalizability: domain specificity considerations regarding the focus on charity fundraising emails, evaluation framework limitations including potential bias in automated assessment criteria, model selection constraints related to the focus on open-source implementations, and temporal considerations regarding the snapshot nature of model capabilities assessment.

Generalizability assessment examines the extent to which findings might apply to broader email generation tasks beyond the specific charitable fundraising domain. This assessment considers the transferability of evaluation methodologies to other persuasive communication contexts, the applicability of model performance patterns to different content domains, and the relevance of identified optimization strategies for broader automated content generation applications.

3.11.3 Research Impact and Future Directions

The methodology establishes foundations for several important research and practical contributions to the field of automated content generation. Research impact includes the development of novel multi-agent evaluation frameworks applicable to other content generation domains, validation of consistency sampling methodologies for reliable model assessment, and demonstration of DPO fine-tuning effectiveness in domain-specific content generation tasks.

Future research directions emerging from this methodology include extension to other persuasive communication domains such as marketing and advocacy campaigns, investigation of cross-cultural effectiveness in fundraising email generation across different geographic and cultural contexts, and development of real-time adaptation mechanisms that adjust generation strategies based on audience response feedback.

Table 3.6: *Future research directions and methodological extensions*

Research Area	Proposed Extension	Expected Impact
[Future research directions table to be completed]		

The comprehensive methodology presented in this chapter provides a robust framework for evaluating language model performance in automated email generation while establishing important precedents for multi-agent evaluation systems and preference-based fine-tuning approaches. The three-stage approach ensures systematic progression from foundational design through implementation to advanced analysis and enhancement, supporting both immediate research objectives and longer-term methodological contributions to the field.

Chapter 4

Results

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Chapter 5

Discussion and Conclusions

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Bibliography

Appendices

Appendix A

Experimental Setup Details

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