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Advanced applications of generative AI in actuarial science: a practical guide

The rapid advancement of artificial intelligence (AI) has led to significant changes in many industries, with actuarial science and insurance among those beginning to experience substantial transformation. Through our research, we have explored the transformative impact of Generative AI (GenAI) on actuarial science through four implemented case studies that move beyond conversational applications such as ChatGPT. Our work illustrates how GenAI offers opportunities to improve predictive accuracy, streamline operational processes, and unlock valuable insights from unstructured data sources throughout the entire insurance value chain.

As Charles Cowling, past president of the International Actuarial Association, has repeatedly emphasized: "AI will not replace actuaries, but actuaries with AI will replace actuaries without AI." This perspective underscores the critical importance of understanding and integrating these emerging technologies into actuarial practice.

IMPROVING CLAIM COST PREDICTION WITH LLM-EXTRACTED FEATURES FROM UNSTRUCTURED DATA

In our first case study, we demonstrated how Large Language Models (LLMs) can transform unstructured textual data into structured, actionable information for claim cost prediction. Using a dataset of 3,000 workers' compensation claims, we showed how LLMs can extract key information from claim descriptions.

Our approach involved employing an LLM to analyze claim descriptions and extract structured information, in particular primary body parts injured, injury causes, and number of body parts injured. We found that the enhanced model incorporating GenAI-extracted features significantly outperformed the baseline model, achieving an 18.1% reduction in RMSE and increasing the R^2 value from 0.267 to 0.508. The feature importance analysis revealed that the most influential predictors included traditional factors like weekly wage and age, alongside several LLM-extracted features such as the main body part injured and the cause of injury.

GENAI-DRIVEN MARKET COMPARISON

Our second case study explored the application of Generative AI to conduct market comparisons, specifically addressing financial and insurance data within annual reports of insurance companies. The process of extracting and harmonizing data for comparative analysis is typically challenging due to varying and non-standardized structures in reports.

We demonstrated how advanced GenAI techniques, specifically Retrieval-Augmented Generation (RAG) and Structured Outputs, can streamline this process. Our methodology involved a three-stage approach examining regulatory capital ratios, discount rates, and cyber risk mitigation strategies from major European insurance groups. We found that multiple runs of the system produced identical results for quantitative fields, demonstrating stability and reproducibility of outputs.

CAR DAMAGE CLASSIFICATION AND LOCALIZATION WITH FINE-TUNED VISION-ENABLED LLMS

Our third case study explored how Large Language Models can improve both classification and contextual understanding of car damage from images – an important task in automotive insurance. We employed

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OpenAI's GPT-4o, a vision-enabled LLM that combines image recognition with natural language understanding.

By fine-tuning this model on a domain-specific dataset of labeled car damage images, we achieved classification performance comparable to traditional Convolutional Neural Network (CNN) models while providing richer contextual insights. The fine-tuned GPT-4o achieved 0.880 for both accuracy and weighted F1 score, outperforming the non-fine-tuned version as well as a CNN. Beyond classification accuracy, our model demonstrated remarkable contextual capabilities, correctly identifying damage locations such as windshield glass shatter or rear bumper dents.

DATA ANALYSIS MULTI-AGENT SYSTEM

Our fourth case study presented a multi-agent system that autonomously analyzes data from a given dataset and generates corresponding reports. The system consists of three specialized agents: a data analysis agent responsible for calculating descriptive statistics and generating visualizations, a report generation agent tasked with synthesizing analytical insights into coherent narratives, and a supervisor agent coordinating the workflow.

We found that this modular design illustrates how complex tasks can be effectively distributed, solved cooperatively, and scaled through agentic AI. Our multi-agent system successfully completed full analytical pipelines within minutes, generating well-structured reports that adhered to predefined formatting requirements. The multi-agent concept offers a modular and adaptable approach for structuring complex workflows, enabling seamless substitution or upgrading of individual agents without disrupting entire systems.

BROADER APPLICATIONS AND FUTURE POTENTIAL

Beyond these specific case studies, Generative AI offers further applications in actuarial and insurance fields, including automated reporting for regulatory documents like Solvency and Financial Condition Reports, enhanced customer interaction through sophisticated chatbots, streamlined claims processing, advanced fraud detection using multimodal analysis, and optimized underwriting assistance.

The potential extends to product development and pricing, where LLMs can design innovative insurance products and perform advanced pricing analyses. Policy renewal optimization, sales enhancement, strategic scenario modeling, and employee training represent additional areas where GenAI can drive significant value.

CHALLENGES AND CONSIDERATIONS

The implementation of GenAI solutions requires careful consideration of multiple challenges. Regulatory compliance with frameworks like the EU AI Act and Digital Operational Resilience Act is crucial, particularly given that LLMs may produce non-replicable or uncertain outputs. Ethics and trustworthiness concerns, including bias mitigation and maintaining transparency, must be proactively addressed.

Privacy, security, and confidentiality represent fundamental considerations when handling sensitive actuarial data. Technical challenges include addressing current limitations such as restricted context windows, output variability, and the propensity of LLMs to hallucinate. Energy efficiency, financial considerations, and the need for interdisciplinary collaboration between actuaries, data scientists, and AI engineers also require careful planning.

SUMMARY

This research demonstrates that Generative AI can enhance predictive accuracy, reduce manual effort, and provide richer contextual insights for diverse actuarial applications. The four case studies collectively show how advanced GenAI approaches – from Large Language Models to multi-agent systems – can effectively improve actuarial practice across risk assessment, underwriting, and claims processing.

The results indicate that responsible adoption is essential as AI becomes increasingly embedded in actuarial workflows. Success requires thoughtful integration that addresses technical robustness, regulatory compliance, cost efficiency, data privacy, and ethical considerations.

With this article, we aim to provide actuaries with a clearer understanding of where Generative AI delivers value, where it may not, and how to critically assess its use.

To enable actuaries to experiment with and adapt these case studies to their specific contexts, we provide practical implementation guides through publicly available Jupyter notebooks (Go to the Github page of the IAA-AITF, select the folder Actuarial-AI-Case-Studies/2025).

Our research paper can be found on arXiv.org: [2506.18942] Advanced Applications of Generative AI in Actuarial Science: Case Studies Beyond ChatGPT. ■