A Telecommunication Engineer’s Guide to Applied Artificial Intelligence

A technical paper prepared for presentation at SCTE TechExpo24

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1. Introduction and Approach

The buzz around Artificial Intelligence (AI) based technology in our industry is palpable. Advances in technology and innovations across industry have driven a fever pitch of intensity and urgency to adopt and leverage innovations in this field. However, it is difficult to decipher and sift through the hype with most products and platforms advertising AI as part of their offerings.

This paper will serve as a practical primer for anyone interested in understanding how common AI technologies work and how to best leverage them in the telecommunications industry. Focus will be on avoiding pitfalls and taking the steps to quickly evaluate and rapidly prototype AI optimization opportunities in the telecommunications space. The concepts here present a mindset change on how to approach this exciting technology. The process of developing AI solutions involves several crucial steps: defining the problem space, curating the required data, architecting the solution, training the model, and rapidly prototyping the opportunity.

1.1. Primer

Artificial Intelligence solutions are distinguished from today's expert systems and algorithmic based development by their ability to leverage knowledge and provide insight or take actions that seem to imply an advanced level of cognition. Arthur C Clarke captures the sentiment in his statement, "Any sufficiently advanced technology is indistinguishable from magic."

Before exploring how to create and implement AI solutions, it is crucial to understand what artificial intelligence is and why it is relevant to the Telecommunications industry. AI is a broad term that encompasses many subfields and applications. In essence, it refers to machines or software imitating human cognitive processes, such as reasoning, learning, decision making, perception, and natural language processing. AI is a continuum of capabilities, ranging from narrow AI, which focuses on specific and well-defined tasks, such as face recognition or spam filtering, to human-like intelligence across a wide range of domains, such as understanding natural language or solving complex problems.

Machine learning is a subset of artificial intelligence that focuses on creating systems that can learn from data and improve their performance with experience, without being explicitly programmed. Machine learning further divides into subcategories; supervised learning, where the system learns from labeled data to predict the correct outputs for new inputs; unsupervised learning, where systems find patterns from unlabeled data and discovers patterns or structures in the data; and reinforcement learning, where systems learn through iterative trial and error incorporating from its own actions and feedback to optimize behavior to achieve goal.

Two key factors have fueled the recent surge of AI.

The first is the convergence of abundant data and powerful computing required to process that data. Machine learning capabilities are significantly increased with more data and the ability to process it more quickly. This potent combination has accelerated development and utility of large language models in machine learning. The increased performance of large language models allows real-time interaction with systems that leverage these models.

Second, a plethora of tools have been released to make these capabilities available to non-subject matter experts. These tools enable non data scientists to train and deploy sophisticated machine learning models that can learn from data and generate predictions or recommendations. The technology industry has jumped on the opportunity to incorporate this capability into their mainstream offerings resulting in an increase in accessibility.

Artificial intelligence and machine learning have many applications and benefits for the telecommunications industry, such as enhancing customer experience, optimizing network performance, increasing operational efficiency, and creating new revenue streams. Some examples of AI solutions in this domain are:

- Chatbots and virtual assistants that can provide personalized and automated customer service, support, and sales.

- Anomaly detection and fault prediction that can monitor network health and performance, identify and diagnose issues, and prevent or mitigate failures.

- Demand forecasting and resource allocation that can predict network traffic and demand and allocate resources accordingly to optimize network quality and capacity.

- Network slicing and orchestration that can create and manage customized network slices for different use cases and customers, such as IoT, gaming, or healthcare.

- Smart pricing and recommendation that can offer dynamic and personalized pricing and plans, and recommend products and services based on customer preferences and behavior.

2. AI Framework

With the abundance of opportunity, it is difficult to focus on the myriad of options available to address needs and challenges in the telecommunications space. This is where the introduction of a framework would help. The AI Framework is designed to systematically develop solutions using AI without getting lost in the allure of copious opportunity. The AI Framework is an abstract model that consists of four major components.

The four major components of the AI Framework are:

1. Problem Space
   The problem space defines what results, insights, and actions are to be achieved by an AI solution. This includes identifying the business objectives, the target audience, the use cases, and the success criteria. The problem space helps to scope the project and focus on the most relevant and valuable aspects.
2. AI Elements
   AI Elements are the technologies that enable an AI capability or capabilities. They include machine learning models, natural language processing, computer vision, speech recognition, and other tools that can perform complex tasks or augment human intelligence. The AI elements help with the selection of the best methods and algorithms to solve the problem and deliver the desired outcomes.
3. Data
   Data is the information that the AI elements need to function. It includes the sources, types, formats, and quality of the data that are used to train, test, and deploy the AI solutions. The data helps to ensure that the AI elements are reliable, accurate, and robust, and that they can handle different scenarios and contexts.
4. Flow
   Flow is the automation and integration that stitches together the data, AI elements, and other systems in such a way as to create the desired outcomes expressed in the problem space. It

includes the workflows, pipelines, APIs, and interfaces that enable the AI solutions to run smoothly and efficiently. The flow helps to optimize the performance, scalability, and usability of the AI solutions.

The AI Framework offers a versatile and systematic approach to tackling (or solving) any challenge. The framework consists of components that can be used to design and implement the solution.

The next section will breakdown and define the components that make up the AI Framework. The combination of the components represents a design pattern that can be leveraged to develop solutions for any problem space (Figure 1).

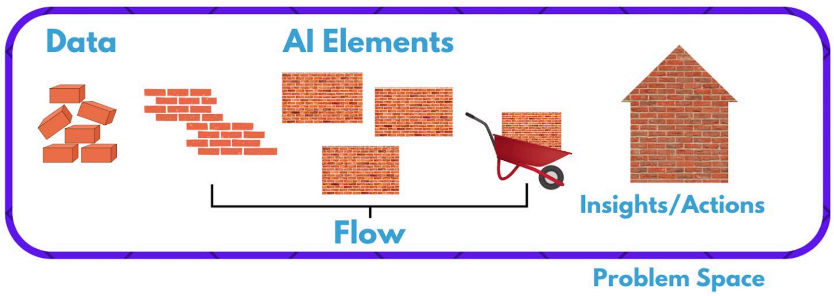

Figure 1- AI Framework Components

3. AI Framework Components

3.1. Problem Space

The Problem Space is the most straightforward component of the framework, but it is critical to being able to properly define the remaining components of the framework. Simply put, it is the problem that you are attempting to address with this solution. For example, are you trying to improve a specific customer experience? Are you looking to utilize data or reports to identify patterns? Do you want to automate a manual process? Once this is known, expand on the information and capture additional insights that would enhance the solution.

"When I automate my target process, I would like to understand the fallout rate and document reasons."

Once the problem is understood and the desired outcomes determined, this information can be used to sketch out potential solution opportunities. We can start to generate a solution outline in the context of the problem you are solving. While this explanation is broad, it lays the foundation for understanding the specifics later. For now, it is important to understand the process before seeing it in action. Figure 2 below illustrates a user interaction with a system that results in either failure or success. The problem in this case is to minimize failure using AI and understand why it is failing.

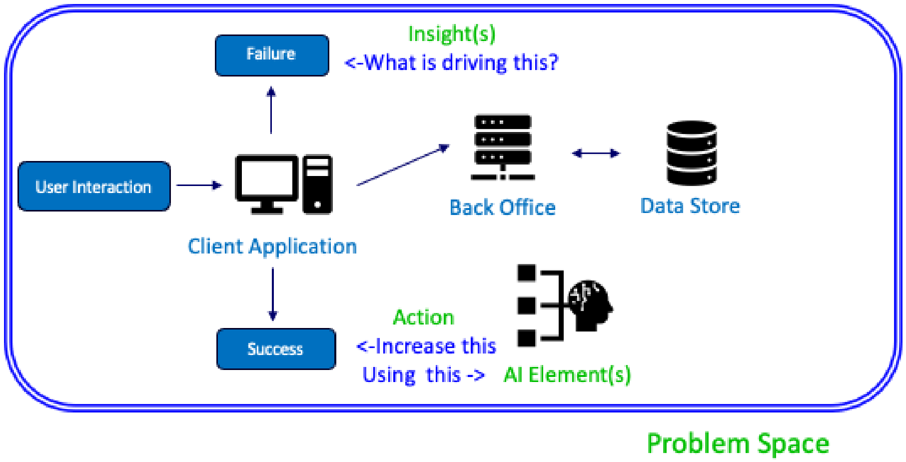

Figure 2 - Problem Space Defined

A commonly observed pitfall in problem solving is known as solution confirmation (Insights, HEC Paris). This involves starting with a particular vendor, solution, or technology and shoehorning the problem to fit the selection. The first step in the AI Framework is to define the problem space so that this is avoided. Separating the problem from the solution, we can first document the existing system "as is". This open-minded approach ensures that as we approach the scenario identifying the specific problem we are trying to address before looking for the AI elements we want to make use of.

3.2. AI Elements

While the term Artificial Intelligence describes technology solutions, it is not a specific technology. AI is a machine characteristic defined by John McCarthy as "the science and engineering of making intelligent machines" (Manning). This can be achieved by combining one or more specific algorithms, services, machine learning models, or interfaces.

For the purposes of mainstream marketing, we will apply the term "AI Elements" to describe constructs that allow systems to exhibit AI behavior. Elements of Artificial Intelligence come in many shapes and sizes and selecting the right element for the solution is key to its success. This is the most crucial part of the AI Framework. Table 1 contains a list of some of the most common AI elements we see today and their potential applications. The list in the table is not exhaustive and is constantly evolving.

Table 1 - Artificial Intelligence Elements

Element	Description	Application Examples
LLM	A type of Machine Learning (ML) that uses large datasets to summarize, predict, and transform information.	Core to a lot of other AI elements
NLP	A capability driven by LLMs to perform Natural Language Processing in a way that is analogous to human communication.	Chatbots, language translation, Sentiment analysis

Generative	An element that has the capability to generate various types of content including visualizations, text, and audio.	Content generation, Generative fallback when combined with other elements
Speech	NLP based element that focuses on speech recognition and response verbalization.	Text to Speech, Speech to Text, Voicebots, Smart IVR
Vision	Computer vision employs algorithms that allow a computer to understand digital images and video.	Facial recognition, Equipment / Infrastructure damage detection
Neural Network	A deep learning method, neural networks solve problems by employing an algorithm that mimics how neurons in the brain function to process information. Requires significant training to continually refine accuracy.	Intelligent network routing rules based on predicted volume on a particular route. Fraud detection
Fuzzy Logic	Fuzzy logic is a method to mathematically derive partial truth from a series of data. Whereas standard logic requires an end result of 0 or 1, Fuzzy Logic may have values between 0 and 1 indicating a confidence score vs absolute value.	Likelihood of equipment failure based on several factors, spam filtering

AI Elements require data as input and can be integrated and layered to form more advanced functionalities, as we will explore in the Flow section below.

Extending the example from Figure 2, In this case we selected Generative AI element. As we would like to use the insights around reasons for failure to create some additional interactions in the client app.

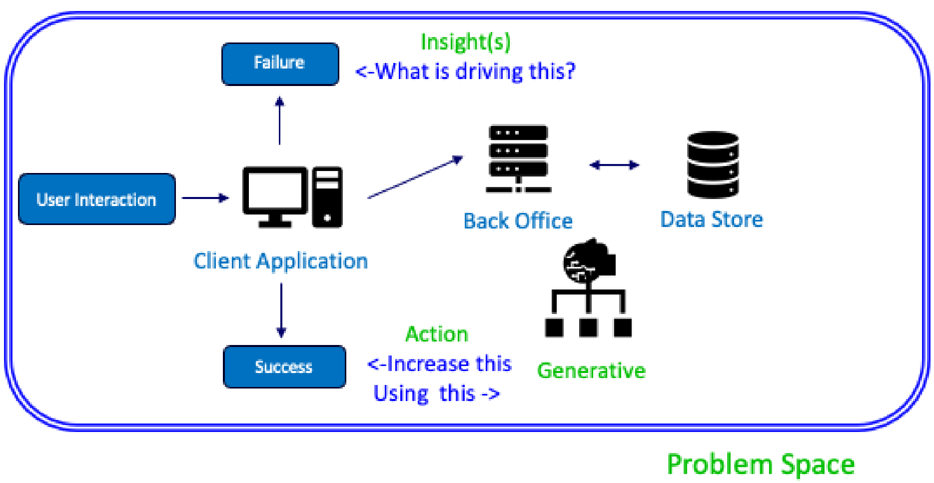

Figure 3 - AI Elements

3.3. Data

Data is the foundation of any AI system, as it provides the information that enables the system to perform various tasks, such as perception, reasoning, learning, or decision making. Data can come from various sources, such as sensors, images, text, speech, or user feedback, and can have different formats, such as structured, unstructured, or semi-structured. The quality, quantity, and diversity of data are crucial factors for the success of an AI system, as they affect its accuracy, reliability, and generalizability.

To leverage AI technologies effectively, it is important to select the appropriate data sources and formats for the specific AI capabilities that are required for the problem domain. For example, if the AI system needs to recognize faces, it would need a large and diverse dataset of images with annotated faces. If the AI system needs to generate natural language summaries, it would need a corpus of texts with corresponding summaries. Depending on the AI capabilities selected, the data may need to be preprocessed or transformed to make it suitable for the AI system. Moreover, the data may need to be updated, monitored, and evaluated regularly to ensure that the AI system remains relevant and consistent with the changing environment and user needs. Data is not only the input but also the output of an AI system, as it can provide valuable insights, feedback, and recommendations that can inform future actions and decisions.

Many of the AI elements shown in Table 1 require the use of machine learning. One of the main steps to prepare data for use in machine learning and LLMs is to perform data analysis and exploration. This involves understanding the characteristics, distribution, and quality of the data. Data analysis and exploration can help identify the features, labels, and relationships that are relevant for the machine learning or LLM task, as well as the potential challenges and limitations of the data, such as bias, imbalance, or inconsistency.

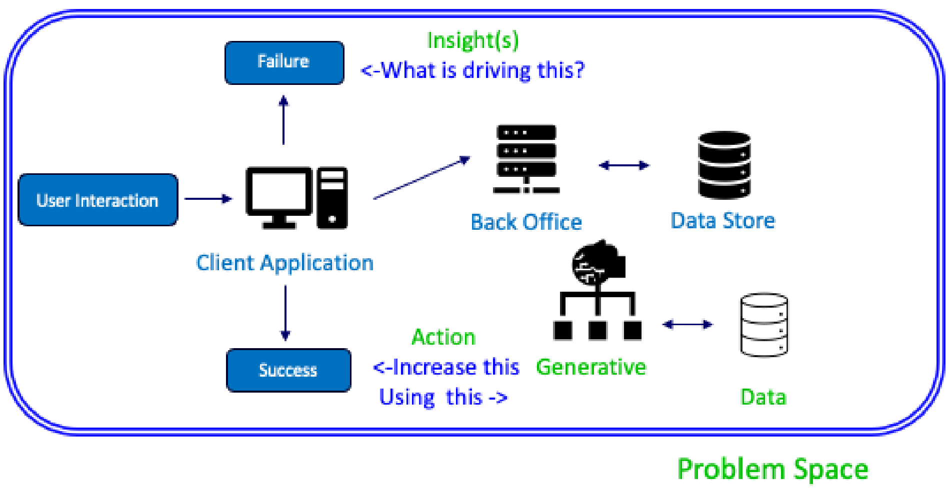

Figure 4 - Data Required

Note on Data Security: If your solution uses sensitive or proprietary data, you need to think about a few crucial things.

1. Data Hosting – Where do you plan to put the prepared data? Is it on prem or in cloud? If in cloud, is it public or private? How exposed is the data and does it conform to your companies' data privacy and security policies?
2. Secure data ingress / egress – When transporting data to and from the systems, is it secure?
3. Model exclusivity / inclusivity – If leveraging a cloud-based LLM or AI element, is your data being used to train the model for other clients? Is there a walled garden / private option that would be more suited to the data being used?

3.4. Flow

Flow refers to elements of the solution required to move data to and through the AI elements to achieve the desired results. This includes workflow, automation and system integration required to produce both the insights and desired actions within your solution.

Flow elements like data preprocessing may be required to prepare data for use in machine learning and LLMs. This could involve applying various techniques and tools to transform the data into a suitable format and structure for the machine learning or LLM task. Data preprocessing and integration can help improve the performance, efficiency, and robustness of the machine learning or LLM system, as well as reduce the complexity and dimensionality of the data, such as by feature extraction, selection, or reduction.

Most of the solutions we want to implement will require integration with existing systems to be most effective. Flow elements also help integrate an AI solution into an existing environment and establish a seamless and secure connection between the AI element and the core systems and data sources that are essential for its functionality.

To integrate an AI element into an existing environment, the following steps are recommended:

1. Identify the core systems and data sources that are relevant and necessary for the AI solution, such as databases, web services, cloud platforms, or other applications.
2. Determine the type and frequency of data that needs to be exchanged between the AI element and the core systems and data sources, such as structured or unstructured data, real-time or batch data, or request-response or publish-subscribe data.
3. Select the appropriate API design and tools that can help to define, document, and connect the data and AI elements for the optimum data exchange and communication.

Rounding out the model, we layer in the flow elements to orchestrate the actions and connect the systems required to provide insights and feedback for the generative AI element. It also connects the generative AI elements to a client application to alter it such that it may account for the failure condition and prevent it in the future.

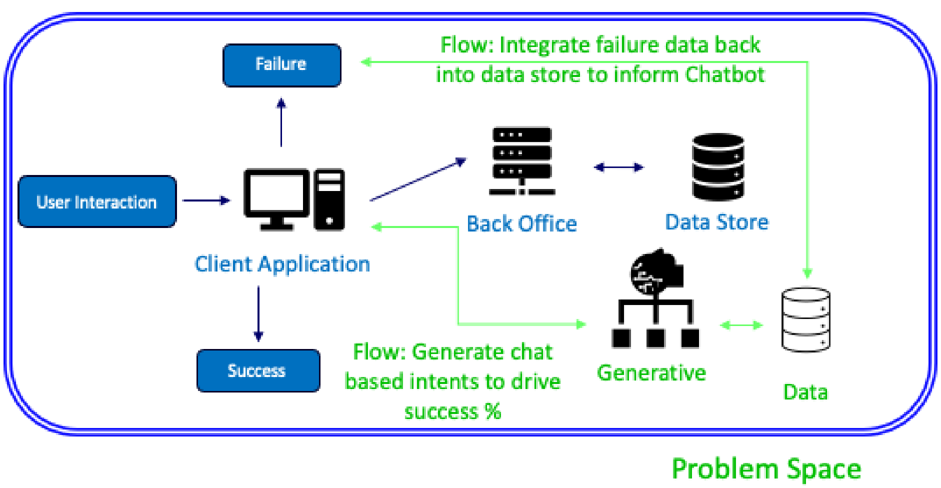

Figure 5 - Flow elements overlayed to complete the framework representation

4. AI Framework in Action

4.1. Putting it together

The components in the preceding section are designed to work in concert to create an abstract model that can be applied to any AI problem space.

The defined problem space sets the table by providing required insights and actions. Based on that, one or more AI elements can be selected. The AI Elements along with required insights and actions will define the data required and how it will need to be preprocessed. Flow elements in the form of integration to other systems, data manipulation by pre or post processing, and triggering actions within the AI elements or integrated systems will follow from the previous decisions.

Now that we understand the framework, let's explore its practical applications in a real-world scenario. The scenario outlined here is simple but effective for promoting further study in this exciting field. The scenario mirrors situations familiar to most who work telecom customer service. The result of the applied AI framework in this scenario is a conceptual design.

4.2. Scenario: Conceptual Design

You have been asked to come up with an option that reduces call volume. Brainstorming several ideas, you decided to pursue a course that increases customer self-service capabilities to increase call deflection and reduce the call volume that must be handled by a call agent.

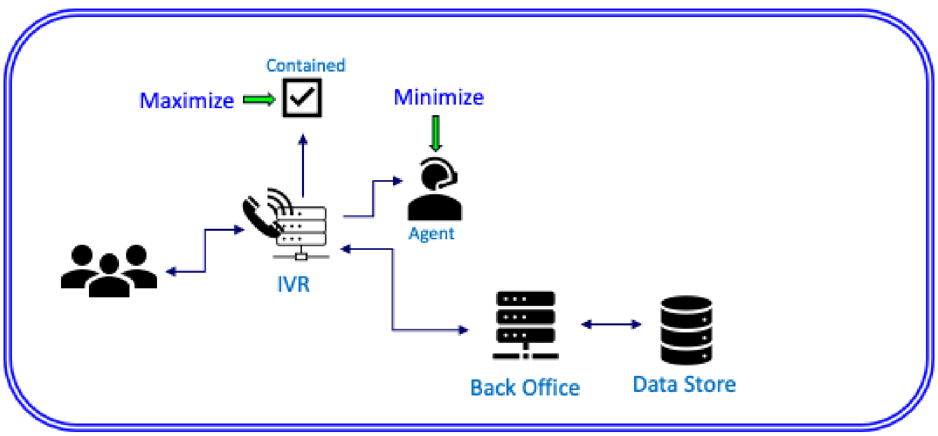

Figure 6 - Scenario Setup

With that goal in mind let us apply our AI Framework to generate a conceptual design to address this need…

4.2.1. Problem Space:

In this scenario, you are tasked with providing a conceptual solution to increase digital self-service effectiveness and increase call deflection. It can be done in several ways; however, the focus here is to start with the IVR system and attempt to increase the amount of deflected incoming calls to the existing digital channels based on customer intent. Expanding on insights of the problem space, it would also be prudent to understand what types of requests are driving the most agent calls.

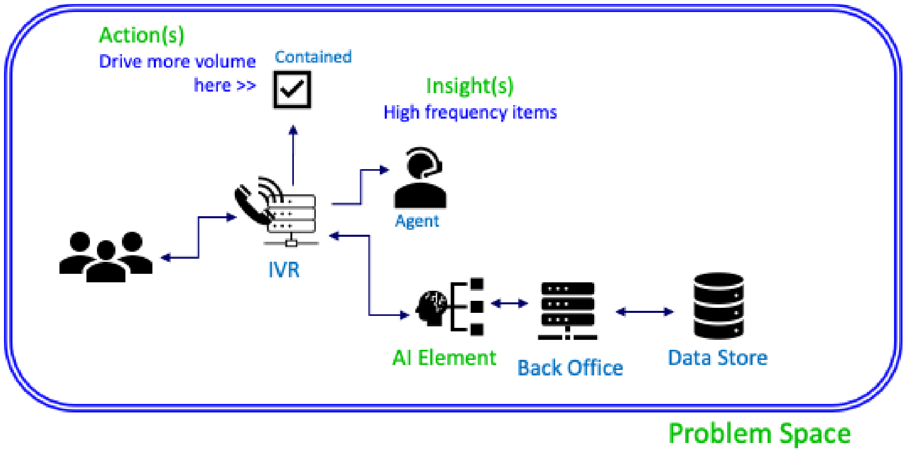

Figure 7 - Scenario Problem Space

4.2.2. AI Elements:

There are many AI elements and potential ways to solve the original problem. In this case, we consider a chatbot leveraging Speech. Initially we would create intents in the chatbot to address calls that bypass the IVR and make it to agents. The primary focus here is to create more opportunities for the customer to self-solve before going to an agent.

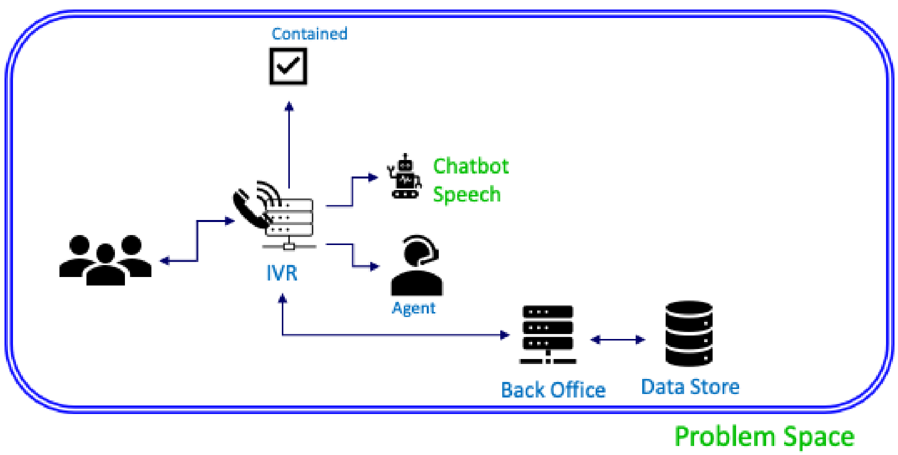

Figure 8 - Scenario AI Elements

4.2.3. Data:

For the implementation of this chatbot, we would need to have a knowledge base repository that could store the datasets required to train and provide information for the chatbot to draw from. Additionally, we would need to get the highest frequency intents that are currently being handled by the agents. This information will give us the highest value items that we can build chatbot handling for in our system.

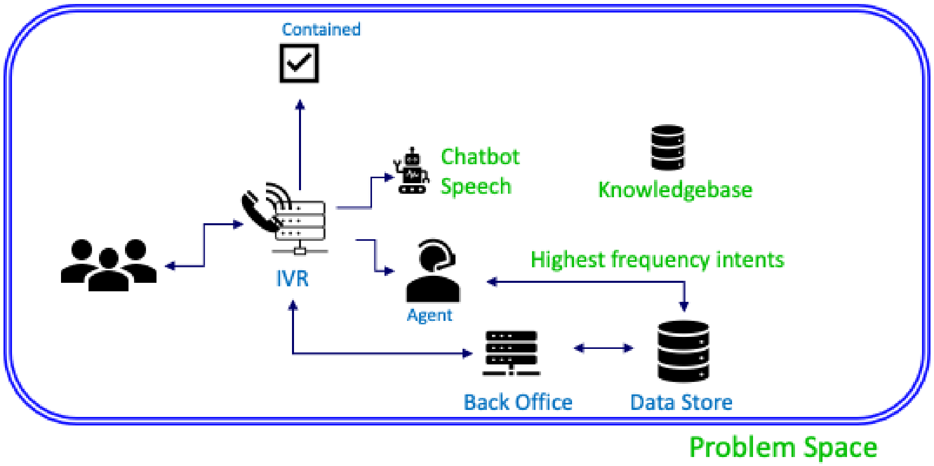

Figure 9 - Scenario Data

4.2.4. Flow:

From considering Figure 9 we know we need to integrate a chatbot capable of speech into our IVR system, we also know we want to feed the knowledge base driving the chatbot with information about the highest frequency intents. We will get those elements integrated with our existing back office datastore.

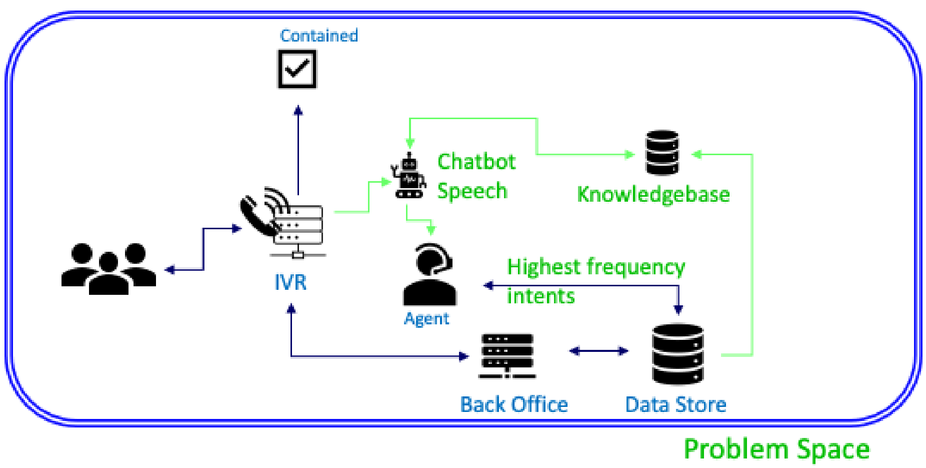

Figure 10 - Scenario Flow

4.2.5. Conceptual Design:

In the resulting conceptual design, we put everything together and also identify a future phase of the project we can add over time. In Figure 11 below, we have incorporated a new AI element for generative AI into the knowledge management / chatbot system to attempt to automate the creation of highest frequency intents. The generative AI component will periodically collect the customer intents that make it to agents and automatically generate content for the chatbot. The idea being that this allows the system to continually improve and adapt to the highest call drivers.

Figure 11 - Scenario Conceptual Design

4.3. Common Pitfalls

4.3.1. Solution Confirmation Bias

Solution confirmation bias is a common pitfall in AI technology applications. Confirmation bias refers to the selection of technology, vendors, or solutions before fully understanding the problem you are solving. With the surge in available AI offerings, it is very tempting to select technologies in the space and then attempt to tailor the problem to make use of the investment. “Generative AI” often gets associated with specific challenges like “to optimize business process x”; and an expectation gets formed that the combination of those things will magically create desired results. Suboptimal results are commonplace in this emerging technology space but rarely because of the maturity of the technology. Most likely because the AI element was selected in the form of a vendor, product or similar and the problem space was derived after.

4.3.2. Data Bias

Data bias in AI refers to the phenomenon where the data used to train or evaluate a machine learning system is not representative of the target population or domain, leading to inaccurate outcomes. Data bias can occur due to various reasons, such as sampling errors, measurement errors, human errors, or intentional manipulation. Data bias can have serious consequences to the quality of the solution. If the data used to train the system is too narrow, the outcomes may be skewed to specific outcomes, hampering predictions. One the other hand, if the training set is too wide, it could lead to hallucinations where incorrect assertions are formed by the model leading to wildly inaccurate results.

4.3.3. Social / Ethical

Identify and address potential ethical and social implications: Machine learning systems can have significant impacts on various aspects of human lives, such as privacy, security, fairness, equality, etc. Therefore, it is crucial to identify and address any potential ethical and social implications of the machine learning systems, such as data privacy, bias, discrimination, accountability, to ensure that they align with the values and norms of the stakeholders and society. This analysis can involve conducting ethical audits, risk assessments, stakeholder consultations, and implementing appropriate safeguards, such as data anonymization, fairness metrics, and explainability methods.

4.3.4. Testing considerations

Unlike traditional solutions, defining traditional test cases and executing them in AI solutions don't provide the same test coverage as it would in traditional solutions. The nature and novelty of the AI elements discussed above lead to nondeterministic results or uncharted paths. To get the best test coverage, a nondeterministic testing regimen may be required. Nondeterministic testing is a methodology that accounts for the inherent uncertainty and variability of AI solutions. Unlike deterministic testing, which assumes that the same input will always produce the same output, nondeterministic testing acknowledges that AI solutions may behave differently in different situations, depending on factors such as data quality, randomness, environment, or user feedback.

Methods for nondeterministic testing are:

- Use multiple metrics: Instead of relying on a single metric to evaluate the performance of an AI solution, use multiple metrics that capture different aspects of the desired outcomes, such as accuracy, precision, recall, f1-score, robustness, fairness, or explainability.
- Use confidence intervals: Confidence intervals are a way of expressing the uncertainty of a metric by providing a range of values that are likely to contain the true value of the metric. Confidence intervals can help assess the reliability and stability of an AI solution by showing how much the metric can vary due to sampling or measurement errors.
- Use statistical tests: Statistical tests are a way of comparing the performance of different AI solutions or the same AI solution under different conditions, by using hypothesis testing and p-values. Statistical tests can help determine whether the observed differences in performance are significant or due to chance, and whether they are consistent or dependent on specific factors.
- Use adversarial testing: Adversarial testing is a way of challenging the robustness and security of an AI solution by exposing it to malicious or unexpected inputs that are designed to fool or degrade the system. Adversarial testing can help identify the weaknesses and vulnerabilities of an AI solution and improve its resilience and trustworthiness.

5. Conclusion

In this paper, we have presented an abstract AI Framework model that can guide the design and development of AI solutions for various domains and applications. The AI Framework consists of four layers: data, algorithms, interfaces, and values. Each layer has its own challenges and requirements that need to be addressed with appropriate methods and tools. We have also demonstrated how the AI Framework can be applied to a practical problem in the technology self-service side of the business and generate a high-level design. Furthermore, we have discussed some common pitfalls that can affect the quality and trustworthiness of AI solutions, such as bias. My hope is that this paper can serve as a useful reference and inspiration for engineers and engineering-minded people who want to explore the exciting and rapidly evolving field of AI within Telecommunications.

Abbreviations

AI	Artificial Intelligence
LLM	Large Language Model
ML	Machine Learning
NLP	Natural Language Processing
SCTE	Society of Cable Telecommunications Engineers

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