# Beyond Prompting: Context Engineering for Production-Grade AI

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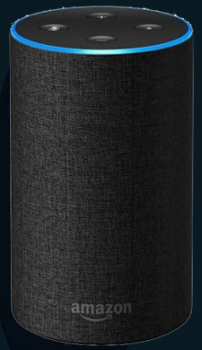
*“Alexa, can you explain what is context engineering”*

*“Hum, I don’t know that one.”*

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# My Jarvis initial implementation

Hoping the LLM will handle everything


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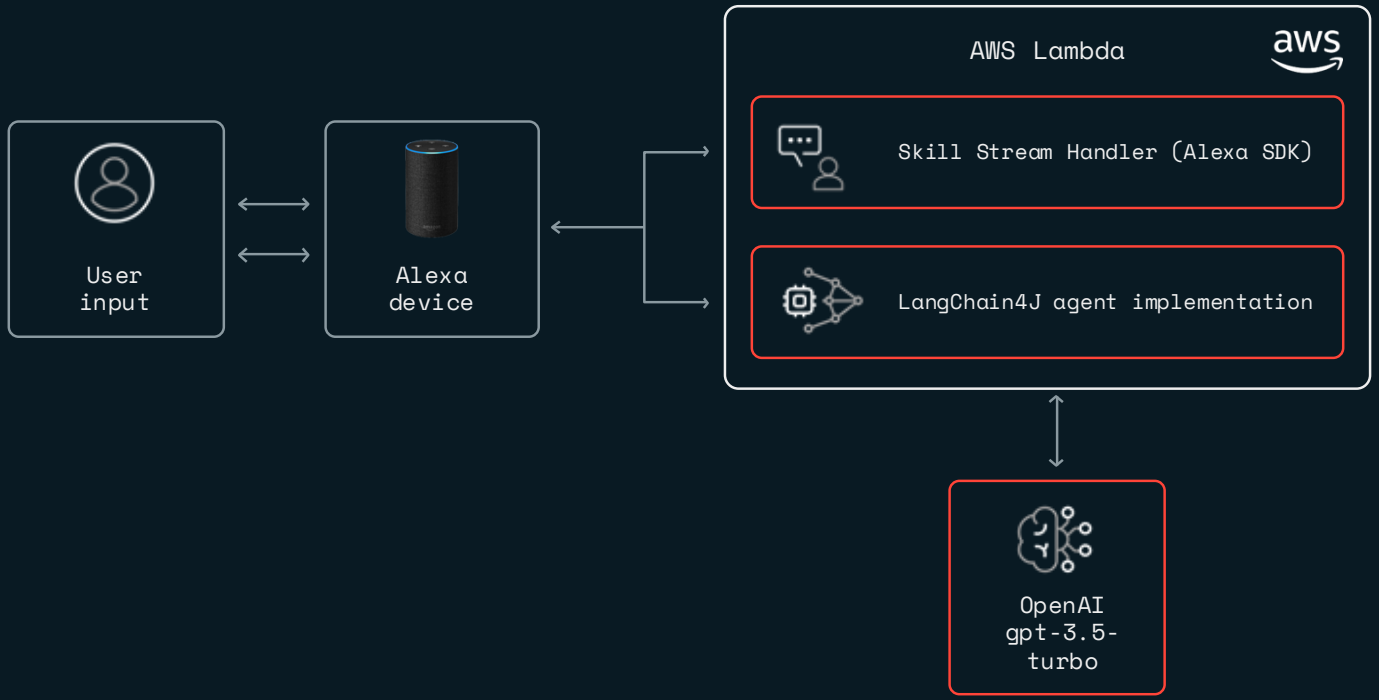
# My naïve initial implementation

## Alexa skill backed by an AWS Lambda function using LangChain4J

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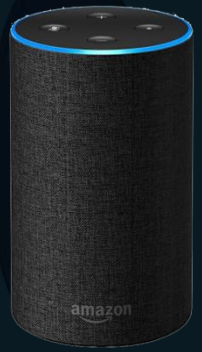
*“Alexa, ask my jarvis to explain what is context engineering?*

*“Context engineering is the discipline of designing, shaping, and delivering the...”*

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J.A.R.V.I.S, are you there?

Using the skill every day made me realize something was missing and the experience was odd.

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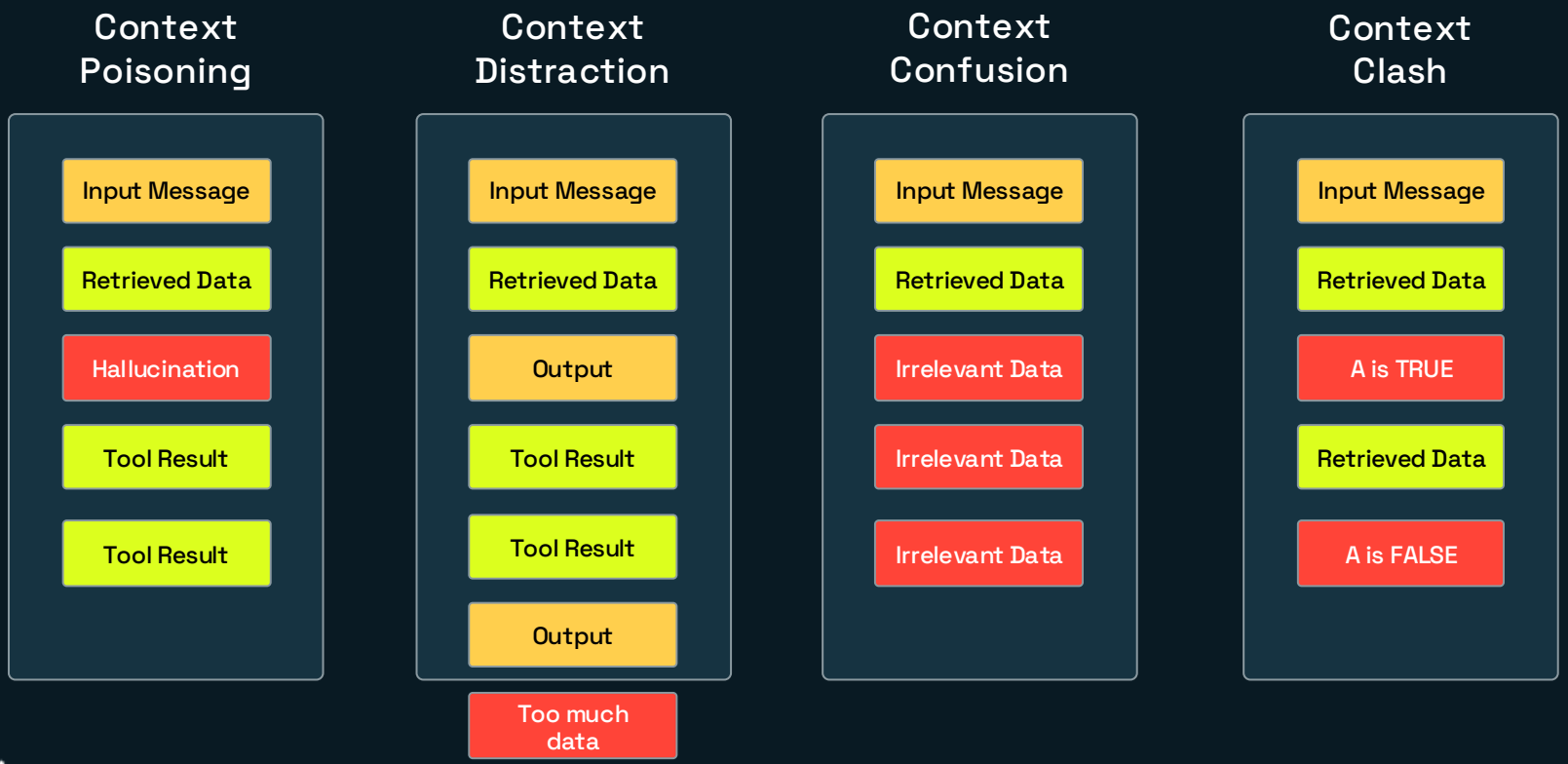
# Different types of context problems

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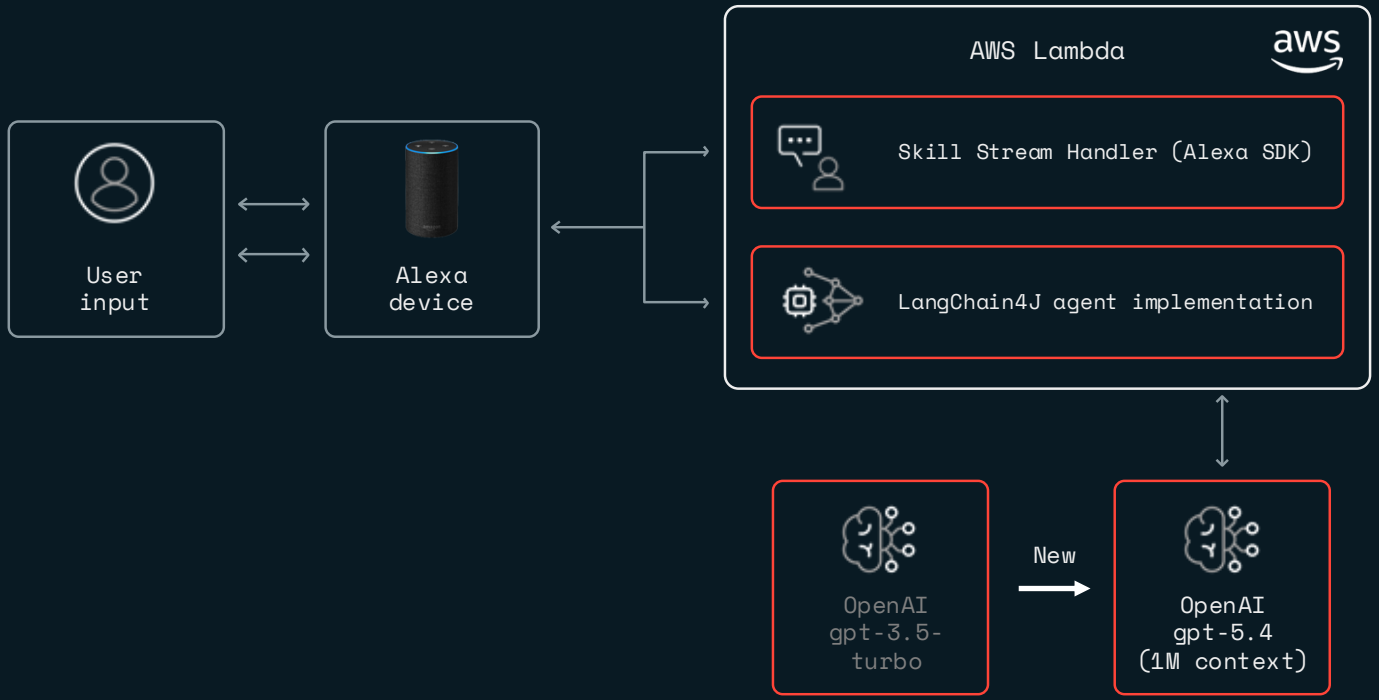
# Using newer models as solution

## Upgrading to newer models with larger context didn't improve

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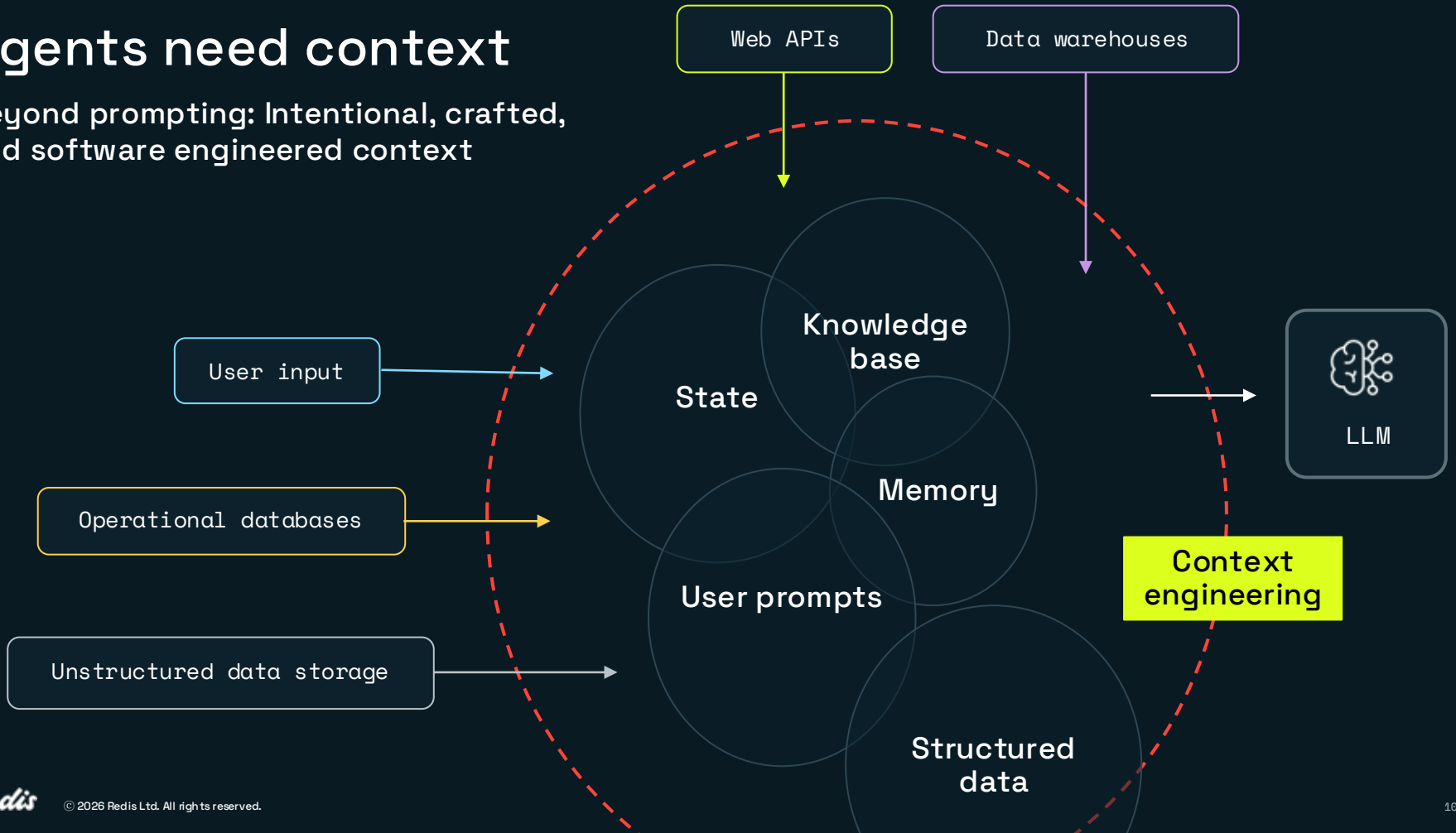
# Agents need context

Beyond prompting: Intentional, crafted, and software engineered context

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# Chapter 1: pragmatically solving each problem

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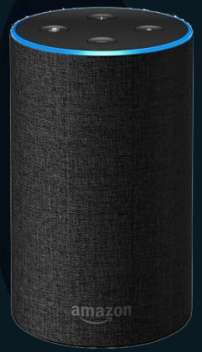
*“Alexa, ask my jarvis to remember about my dentist appointment tomorrow at 10:00am”*

*“Sure. I created a reminder for July 15, 2021, at 10:00am.”*

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LLMs have no concept of what day it is. Every query needs temporal context.

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# Implementing essential tools

Solving the problem with date and time tracking

```
public class DateTimeTool {

    private static final ThreadLocal<String> userTimeZone =
            ThreadLocal.withInitial(() -> "America/New_York");

    @Tool("Set the user's timezone for this request")
    public String setUserTimeZone(String timeZone) {
        userTimeZone.set(timeZone);
        return "Timezone set to: " + timeZone;
    }

}
```

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# Implementing essential tools

Solving the problem with date and time tracking

```
ChatAssistant chatAssistant =
            AiServices.builder(ChatAssistant.class)
                    .chatModel(chatModel)
                    .tools(List.of(dateTimeTool))
                    .build();

String response = chatAssistant.chat(systemPrompt, query);
```

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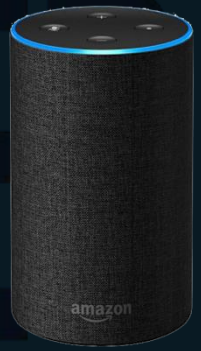
Wakes up at 10:00am...




*“This is a reminder about your dentist appointment.”*

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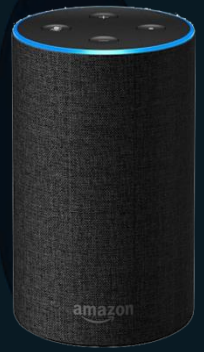
*“Alexa, ask my jarvis to confirm that my name is Ricardo.”*

*“Nice to meet you, Ricardo.”*

*“Alexa, ask my jarvis to recall what is my name?”*

*“Apologies, I don’t know you.”*

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LLMs are stateless. Every request is a blank slate.

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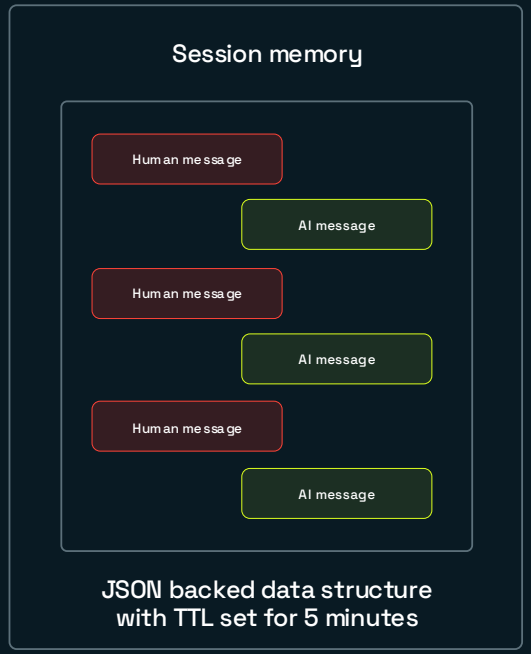
# Implementing short-term memory

## Implementing the memory backend persistence

```
public class WorkingMemoryStore
    implements ChatMemoryStore {


    public List<Message> getMessages() {}


    public void updateMessages(
        Object memoryId,
        List<Message> messages
    ) {}
}
```

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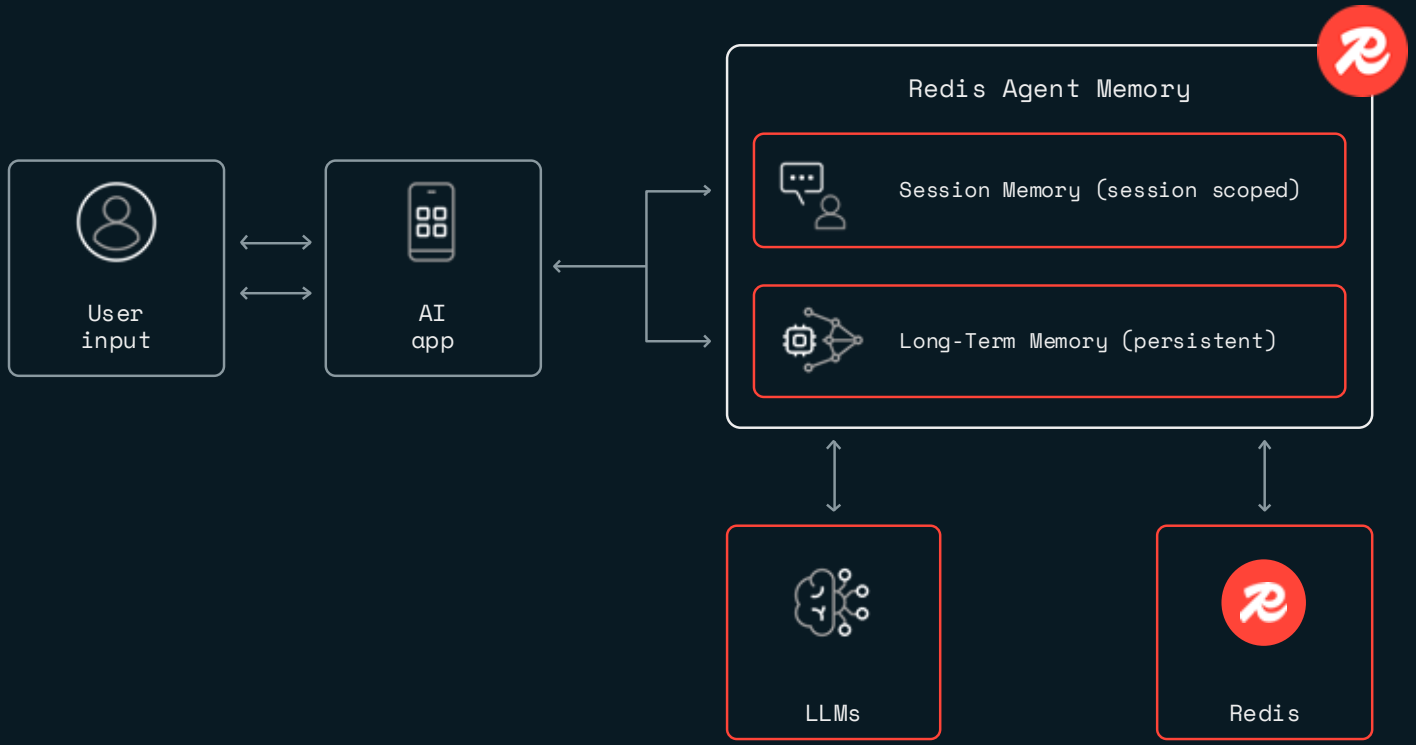
# Redis Agent Memory

## RESTful API and MCP server for managing dual-tiered agent memory

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# Implementing short-term memory

Using the sliding window chat memory implementation

```
private ChatMemory getChatMemory(String userId) {
    ChatMemoryStore chatMemoryStore = WorkingMemoryStore.builder()
            .agentMemoryServerUrl(REDIS_AGENT_MEMORY_SERVER_URL)
            .maxContextWindow(Integer.parseInt(OPENAI_CHAT_MAX_TOKENS))
            .build();

    return MessageWindowChatMemory.builder()
            .id(userId)
            .chatMemoryStore(chatMemoryStore)
            .maxMessages(10)
            .build();
}
```

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# Implementing short-term memory

Using the chat memory system with the AI service

```
ChatAssistant chatAssistant =
            AiServices.builder(ChatAssistant.class)
                    .chatModel(chatModel)
                    .tools(tools)
                    .getChatMemory(getChatMemory(userId))
                    .build();

String response = chatAssistant.chat(systemPrompt, query);
```

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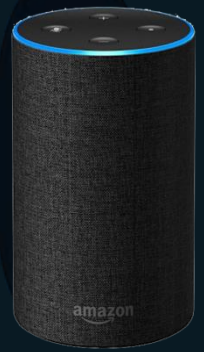
*“Alexa, ask my jarvis to confirm that my name is Ricardo.”*

*“Nice to meet you, Ricardo.”*

*“Alexa, ask my jarvis to recall what is my name?”*

*“Your name is Ricardo.”*

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# Lessons learned

- Built-in implementation from LangChain4J had issues with tool calling. It call tools in a loop.
- Capping the number of messages with a fixed number sounded very arbitrary. Decided to keep all messages for better experiences.

```
return MessageWindowChatMemory.builder()
    .id(userId)
    .chatMemoryStore(chatMemoryStore)
    .maxMessages(10)
    .build();
```

```
return WorkingMemoryChat.builder()
    .id(userId)
    .chatMemoryStore(chatMemoryStore)
    .build();
```

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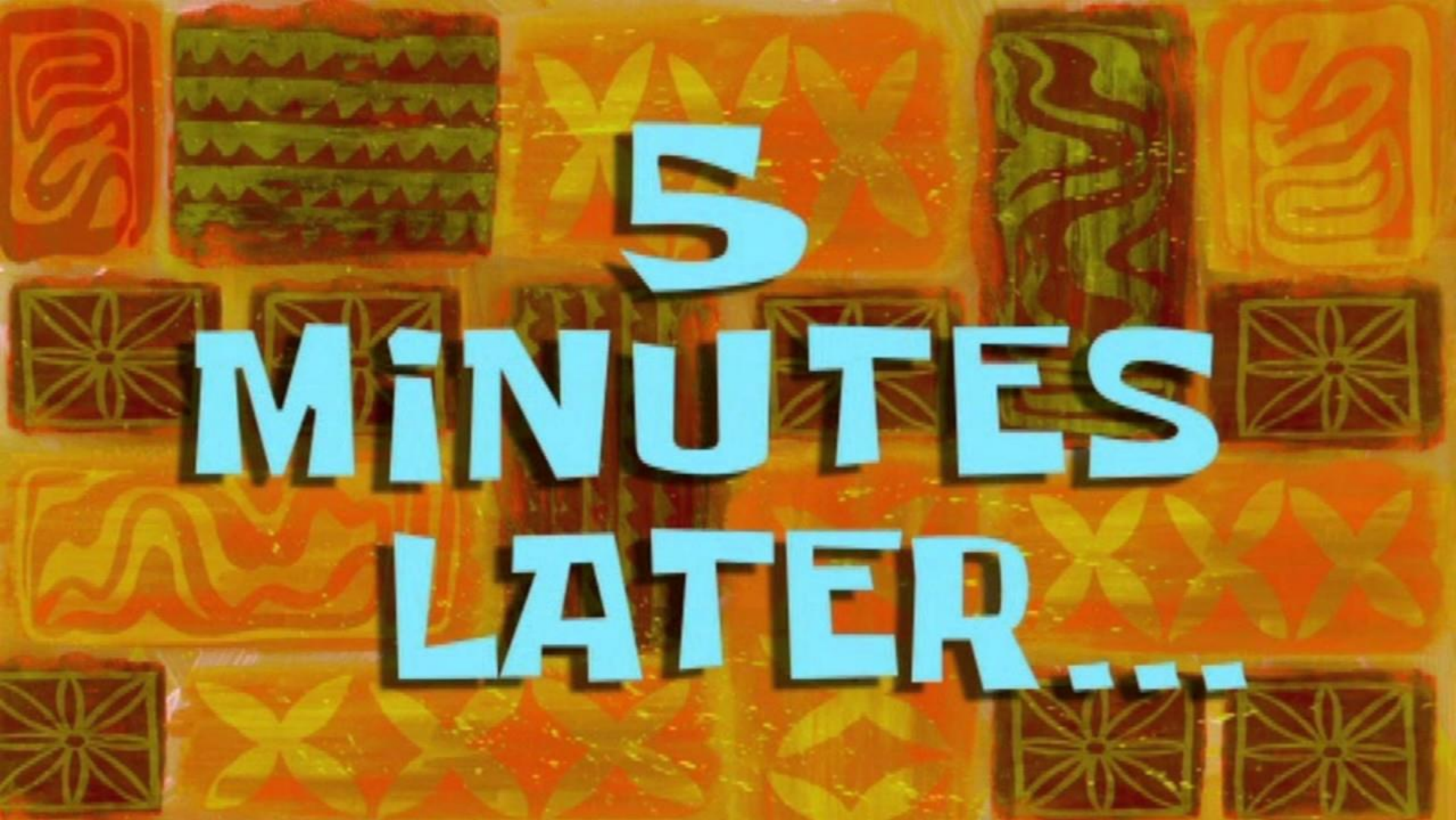
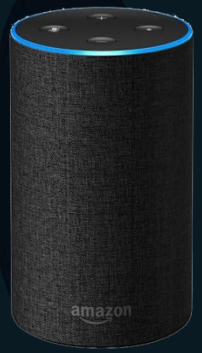

5
MINUTES
LATER...

*“Alexa, ask my jarvis to recall what is my name?”*

*“Apologies, I don’t know you.”*

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The context must use
long-term memories
from the user as well.

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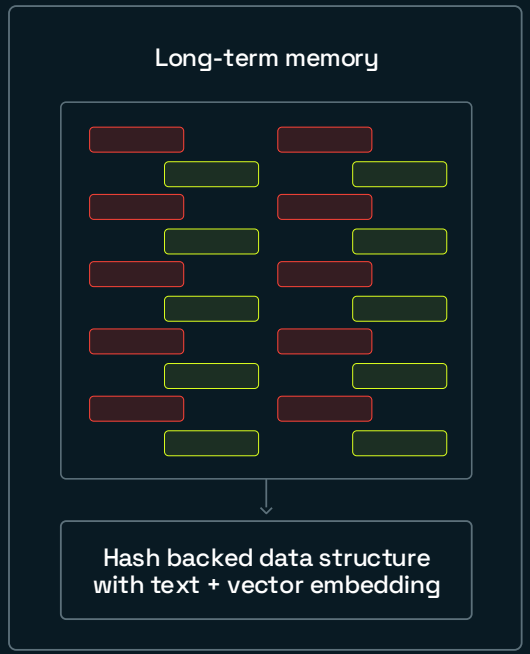
# Implementing long-term memory

## Building a content retriever for memories

```
public interface ContentRetriever {
    List<Content> retrieve(Query query);
}

private ContentRetriever getLongTermMemories(
   String userId) {
   return query -> memoryService.getMemories(
      userId, query.text())
         .stream()
         .map(Content::from)
         .toList();
}
```

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# Implementing long-term memory

## Using the content retriever with the AI service

```
ChatAssistant chatAssistant =
          AiServices.builder(ChatAssistant.class)
                  .chatModel(chatModel)
                  .tools(tools)
                  .getChatMemory(getChatMemory(userId))
                  .contentRetriever(getLongTermMemories(userId))
                  .build();

String response = chatAssistant.chat(systemPrompt, query);
```

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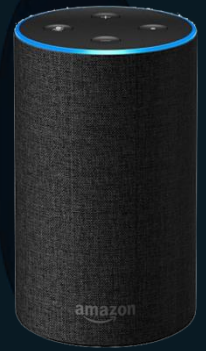
“Alexa, ask my jarvis to confirm my dentist appointment.”

“Very well. It is confirmed.”




“Alexa, ask my jarvis to verify what is for tomorrow?”

“You have dentist at 10 am.”

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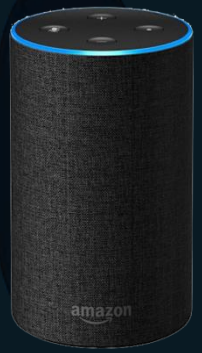
MANY, MANY
MINUTES LATER...

*“Alexa, ask my jarvis to verify what is for tomorrow?”*

*“You have dentist at 10 am.”*

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# Lessons learned

- The app's multi-tenancy required vector search with post-filtering. The concept of owner id.
- Deciding how many rows to return for the top-k vector search required many hours of testing.

```
public List<String> searchUserMemories(
   String userId, String memory) {
   var searchRequest = Map.of(
      "text", memory,
      "limit", Integer.parseInt(
         USER_MEMORIES_SEARCH_LIMIT),
      "filter", Map.of(
         "ownerId", Map.of("eq",
         sanitizeOwnerId(userId)),
         "namespace", Map.of("eq",
         LONG_TERM_MEMORY_NAMESPACE))
    );

    return extractTexts(executeSearch(
       searchRequest));
}
```

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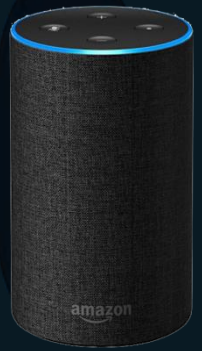
*“Alexa, ask my jarvis to confirm what is the code for the wireless touchpad in the garage?”*

*“I’m sorry, but I don’t have access to this information.”*

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The context may require user memories or data from knowledge bases.

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# Dual layer long-term memory system

## Replacing the content retriever with a retrieval augmentator

```
private RetrievalAugmentor createRetrievalAugmentor(String userId) {
    Map<ContentRetriever, String> retrievers = Map.of(
            getLongTermMemories(userId), "User specific memories",
            getGeneralKnowledgeBase(), "General knowledge base"
    );

    LanguageModelQueryRouter router = LanguageModelQueryRouter.builder()
            .chatModel(chatModel)
            .retrieverToDescription(retrievers)
            .fallbackStrategy(FallbackStrategy.ROUTE_TO_ALL)
            .build();

    return DefaultRetrievalAugmentor.builder().queryRouter(router).build();
}
```

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# Dual layer long-term memory system

Replacing the content retriever with a retrieval augmentator

```
ChatAssistant chatAssistant =
        AiServices.builder(ChatAssistant.class)
            .chatModel(chatModel)
            .chatMemory(getChatMemory(userId))
            //.contentRetriever(getLongTermMemories(userId))
            .retrievalAugmentor(createRetrievalAugmentor(userId))
            .tools(tools)
            .build();

String response = chatAssistant.chat(systemPrompt, query);
```

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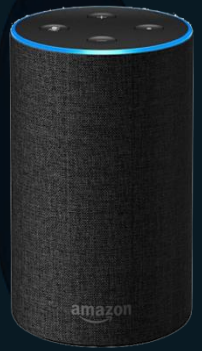
*“Alexa, ask my jarvis to confirm what is the code for the wireless touchpad in the garage?*

*“You can unlock your garage door with the code 7121. Is there anything else?”*

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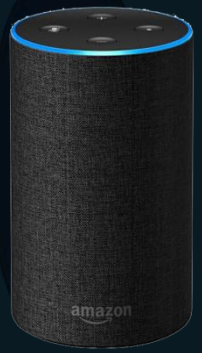
*“Alexa, ask my jarvis to recall who was the John Doe I have meet.*

*“John Doe was…”*

*“Alexa, ask my jarvis to recall where he lives?*

*“Where lives who?”*

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# Improving query retrieval quality

Using a query transformer to implement compressing

```
QueryTransformer queryTransformer =
        new CompressingQueryTransformer(chatModel);


return DefaultRetrievalAugmentor.builder()
    .queryTransformer(queryTransformer) // Added
    .queryRouter(router)
    .build();
```

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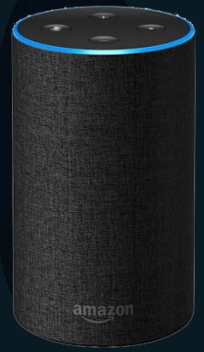
*“Alexa, ask my jarvis to recall who was the John Doe I have meet.”*

*“John Doe was…”*

*“Alexa, ask my jarvis to recall where [he → John Doe] lives?”*

*“He lives in Boston, MA.”*

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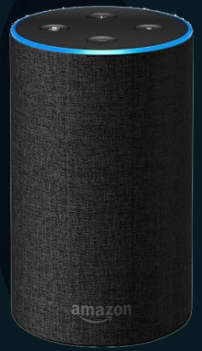
*“Alexa, ask my jarvis to confirm what is my favorite color?*

*“Your favorite color is black. Also, you love writing code using Java.”*

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The model is dumping everything retrieved. It needs to be selective.

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# Prompt design for few-shots

Creating a template that prompts can leverage

```
ContentInjector contentInjector = DefaultContentInjector.builder()
    .promptTemplate(PromptTemplate.from(
        "{{userMessage}}\n\n[Context]\n{{contents}}"
    )).build();

return DefaultRetrievalAugmentor.builder()
    .contentInjector(contentInjector) // Added
    .queryTransformer(queryTransformer)
    .queryRouter(router)
    .build();
```

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# Prompt design for few-shots

Using the template with structured prompts

[Example 1 - Ignoring irrelevant context]
User: ”What programming language do I use?”
Context: ”Favorite color is black”, ”Birthday is October 5th”, ”Enjoys Java”
Response: ”You enjoy coding in Java.”

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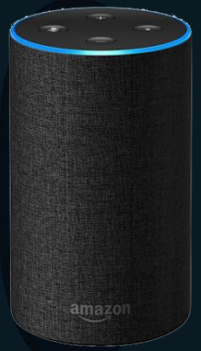
*“Alexa, ask my jarvis to confirm what is my favorite color?*

*“Your favorite color is black.”*

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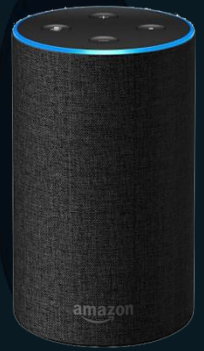
*“Alexa, ask my jarvis to recall which PR is a priority right now?”*

*“Adding support for JSON and going to dentist, are the priority for this week.”*

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The retrieved context data was semantically correct but irrelevant to the query.

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# Improving context quality with reranking

## Creating a new scoring model based on Cohere API

```
ScoringModel scoringModel = CohereScoringModel.builder()
        .apiKey(COHERE_API_KEY)
        .modelName(COHERE_MODEL_NAME)
        .build();
```

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# Improving context quality with reranking

Using the content aggregator with a scoring model

```
ContentAggregator contentAggregator =
   ReRankingContentAggregator.builder()
      .scoringModel(scoringModel)
      .minScore(0.8)
      .build();

return DefaultRetrievalAugmentor.builder()
   .contentInjector(contentInjector)
   .queryTransformer(queryTransformer)
   .queryRouter(router)
   .contentAggregator(contentAggregator) // Added
   .build();
```

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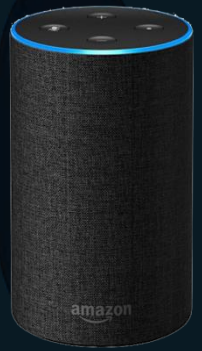
*“Alexa, ask my jarvis to recall which PR is a priority right now?”*

*“Adding support for JSON is the priority for this week.”*

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# Lessons learned

- Using a local model like ms-marco-MiniLM-L-6 (ONNX format) is better, but deployment archive became too large for a AWS Lambda function.
- Changing models made me re-evaluate the min score model used. The precision changed with different values.

**JAR file maximum size (direct):** 50MB
**JAR file maximum size (with S3):** 250MB

**JAR file with local model:** 415MB

```
ContentAggregator contentAggregator =
    ReRankingContentAggregator.builder()
        .scoringModel(scoringModel)
        .minScore(0.8)
        .build();
```

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# Chapter 2: Dealing with the monthly cost

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# How much a single Alexa interaction cost?

A single day costs $0.09 per user and $8.65 per month

## Cost with LLM

One Alexa query triggers 4–5 LLM calls to the OpenAI API. It includes query routing, query compression, and tool calling (at least 3 tools)

→ Single user
- 10 queries per day
- $4.20 per month

→ Three users
- 10 queries each per day
- $12.60 per month

## Cost with Cohere

**During the reranking process, each call from Alexa triggers 1 Cohere call for the multilingual-v3.0 model which costs $2 per 1,000 searches**

→ Single user
- 10 queries per day
- 10 rerank calls = $0.02

→ Three users
- 10 queries each per day
- 30 rerank calls = $0.06

## Context growth cost

**Context persist across all user sessions. Every call re-sends the full session history, making token usage grow linearly and not flat**

→ Single user
- 10 queries per day
- 22,700 tokens = $0.0708

→ Three users
- 10 queries each per day
- 67,800 tokens = $0.2123

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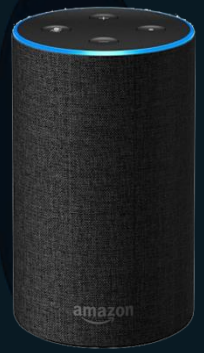
*“Alexa, ask my jarvis to recall…”*

[Adds question data to context]

*“Some elaborated answer…”*

[Adds answer data to context]

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# Compressing the context for efficiency

Making the short-term memory efficient and costly effective

```
private ChatMemory getChatMemory(String userId) {
    ChatMemoryStore chatMemoryStore = WorkingMemoryStore.builder()
            .agentMemoryServerUrl(REDIS_AGENT_MEMORY_SERVER_URL)
            .maxContextWindow(OPENAI_CHAT_MAX_TOKENS)
            .build();

    return TokenWindowChatMemory.builder() //New implementation
            .id(userId)
            .maxTokens(OPENAI_CHAT_MAX_TOKENS,
                new OpenAiTokenCountEstimator(OPENAI_MODEL_NAME))
            .chatMemoryStore(chatMemoryStore)
            .build();
}
```

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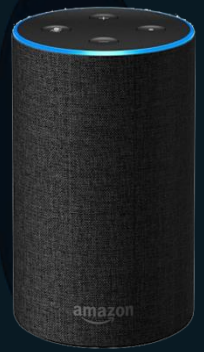
*“Alexa, ask my jarvis to recall who is coming for dinner tonight?”*

*“Both John and Susan are…”*

*“Alexa, ask my jarvis to recall am I having dinner with who tonight?”*

*“Both John and Susan are…”*

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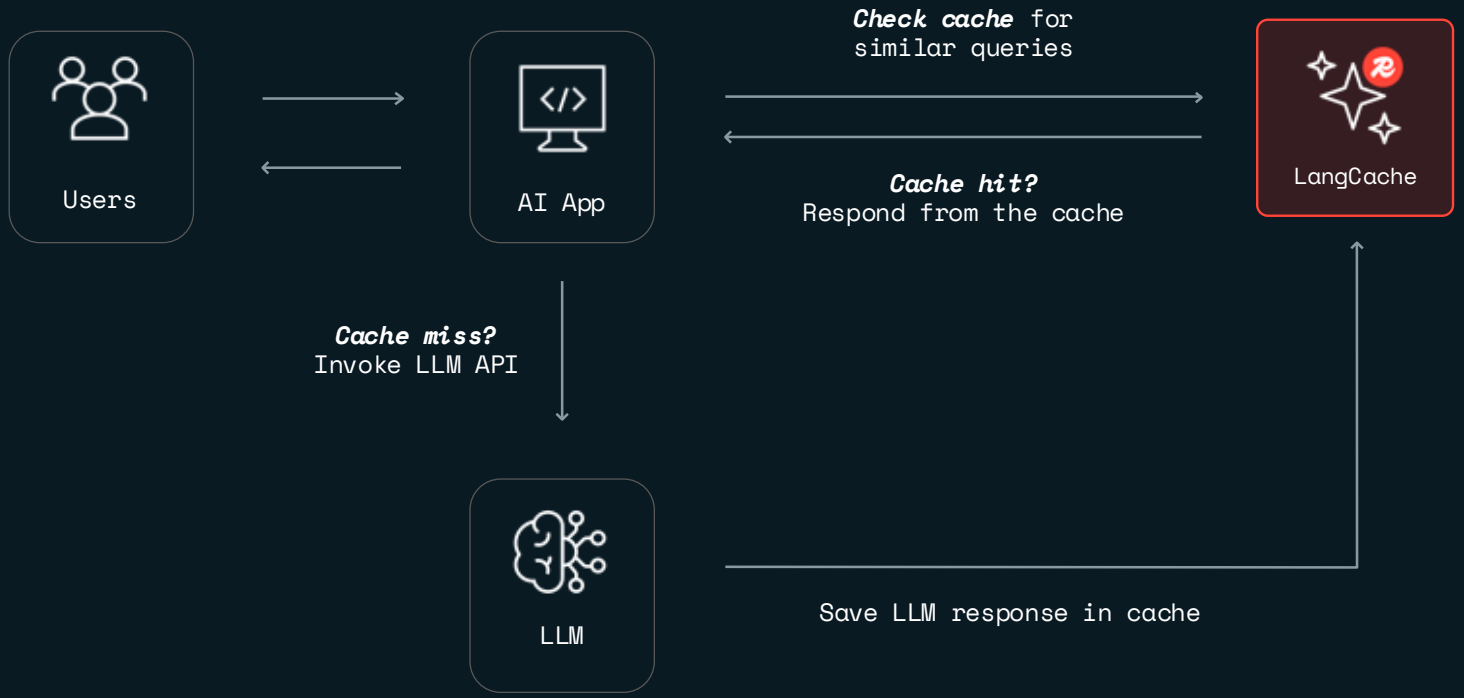
# Cutting LLM cost calls with semantic caching

## Reusing previously answered questions with Redis LangCache

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# Cutting LLM cost calls with semantic caching

Reusing previously answered questions with Redis LangCache

```
String response = langCacheService.searchForResponse(query)
    .orElseGet(() -> {
        String response = chatAssistant.chat(systemPrompt, query);
        langCacheService.addNewResponse(query, response);
        return response;
    });
```

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Context engineering isn't a feature, it's architecture. Get this right and everything else gets easier.

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