

US Patent & Trademark Office

Patent Public Search | Text View

United States Patent	12387050
Kind Code	B1
Date of Patent	August 12, 2025
Inventor(s)	Galvin; Brian et al.

Multi-stage LLM with unlimited context

Abstract

A system and method for efficient natural language processing combines large and small language models with a thought caching architecture. The system includes a router that directs prompts either to a large language model for thought generation or to a thought cache containing previously generated thoughts. When using the large model, generated thoughts are combined with the original prompt and routed through a smaller language model to produce responses. The thought cache stores reasoning patterns that can be retrieved and reused, eliminating the need to regenerate similar thoughts for related prompts. The system supports both local and cloud-based caching, enabling personal and enterprise-wide thought storage and retrieval. This architecture reduces computational overhead while maintaining reasoning capabilities, effectively extends context windows beyond traditional limits, and enables efficient scaling across different deployment scenarios. The system can operate with reduced resources by leveraging cached thoughts without requiring constant access to the large model.

Inventors:	Galvin; Brian (Silverdale, WA), McCord; Alan (Forney, TX)
Applicant:	AtomBeam Technologies Inc. (Moraga, CA)
Family ID:	1000008489027
Assignee:	ATOMBEAM TECHNOLOGIES INC. (Moraga, CA)
Appl. No.:	19/051193
Filed:	February 12, 2025

Publication Classification

Int. Cl.: G06F40/30 (20200101); G06F16/332 (20190101); G06F16/3329 (20250101)

U.S. Cl.:

CPC G06F40/30 (20200101); G06F16/3325 (20190101); G06F16/3329 (20190101);

Field of Classification Search

CPC: G06F (40/211); G06F (40/253); G06F (40/268); G06F (40/284); G06F (40/30); G06N (3/08)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
12223456	12/2024	Manohar	N/A	G06F 40/30
2002/0091801	12/2001	Lewin	709/219	H04L 63/08
2018/0174055	12/2017	Tirumale	N/A	H04L 51/04
2019/0174514	12/2018	Ramesh	N/A	G06Q 50/40
2020/0034914	12/2019	Boss	N/A	G06Q 30/0633
2020/0073983	12/2019	Sen	N/A	G06F 16/243
2020/0285704	12/2019	Rajani	N/A	G06F 40/284
2020/0336562	12/2019	Luft	N/A	H04L 67/2885
2020/0351344	12/2019	Das Gupta	N/A	H04L 41/16
2021/0073808	12/2020	Gu	N/A	G06Q 20/367
2021/0406224	12/2020	Neufeld	N/A	G06F 16/1873
2022/0138156	12/2021	Wang	707/740	H04L 67/568
2023/0316006	12/2022	Tunstall-Pedoe	704/9	G06N 3/0442
2024/0104391	12/2023	Higgins	N/A	G06N 3/092
2024/0160955	12/2023	Zhao	N/A	G06N 5/01
2024/0256965	12/2023	Chung	N/A	G06N 20/00
2024/0354320	12/2023	Procter	N/A	G06F 40/103
2024/0386015	12/2023	Crabtree	N/A	G06F 16/9024
2024/0411809	12/2023	Najafirad	N/A	G06F 16/7837
2024/0428008	12/2023	Abraham	N/A	G06F 16/3329
2025/0028882	12/2024	Ataei	N/A	G06F 30/12
2025/0094455	12/2024	Bista	N/A	G06F 16/3329
2025/0148203	12/2024	Pan	N/A	G10L 15/26
2025/0165718	12/2024	Seo	N/A	G06F 40/35
2025/0191369	12/2024	Huang	N/A	G06V 20/49

OTHER PUBLICATIONS

Ramirez et al., Cache & Distil: Optimising API Calls to Large Language Models, 2023, ournal reference: Findings of the Association for Computational Linguistics: ACL 2024, Subjects: Computation and Language (cs.CL); Machine Learning (cs.LG), arXiv:2310.13561 [cs.CL] pp. 1-14 (Year: 2024). cited by examiner

Schroeder, title={VectorQ: Advanced Semantic Prompt Caching With Dynamic Thresholds and Performance-Based Clustering}, School OfComputation, Information and Technology—Informatics, pp. 1-63, 2024 (Year: 2024). cited by examiner

Gao et al., title={Memory sharing for large language model based agents}, journal={arXiv preprint arXiv:2404.09982}, pp. 1-14 (Year: 2024). cited by examiner

Gim, In et al., “Prompt Cache: Modular Attention Reuse for Low-Latency Inference”, Proceedings of the 5th MLSys Conference, Santa Clara, CA, USA, 2024. cited by applicant

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) Priority is claimed in the application data sheet to the following patents or patent applications, each of which is expressly incorporated herein by reference in its entirety:

(2) None.

BACKGROUND OF THE INVENTION

Field of the Invention

(3) The present invention relates to systems and methods for efficient natural language processing using a combination of large and small language models with thought caching capabilities to reduce computational overhead while maintaining reasoning capabilities.

Discussion of the State of the Art

(4) Language models have evolved significantly in recent years, with modern architectures demonstrating remarkable capabilities in natural language processing, reasoning, and generation tasks. These large language models (LLMs) have become increasingly sophisticated, processing and generating human-like text across a wide range of applications. As these models have grown in capability, they have also grown substantially in size, with some models containing hundreds of billions of parameters.

(5) Modern LLMs process input prompts through complex architectures consisting of encoder and decoder blocks with attention mechanisms. Recent developments have revealed that these models often engage in an internal reasoning process, generating “thoughts” about a prompt before producing a final response. These thoughts represent the model's step-by-step reasoning and analysis of the input prompt. While some models expose these thoughts to users, others keep them internal to the model's processing pipeline. These reasoning steps have proven important to the model's ability to provide accurate and contextually appropriate responses.

(6) The computational resources required to run these large models present significant challenges for widespread deployment and real-time applications. The memory and processing requirements often necessitate specialized hardware and substantial computational infrastructure. Additionally, context windows in current architectures limit the amount of information that can be processed in a single session, constraining the model's ability to maintain long-term context and engage in extended conversations. While various solutions like retrieval-augmented generation have been proposed to address context limitations, these systems typically rely on document retrieval rather than leveraging the model's own reasoning processes.

(7) The deployment of these models also presents challenges in terms of scalability and accessibility. Current solutions often require either substantial local computing resources or constant connection to cloud services with significant computational capacity. This limits the practical applications of these models, particularly in scenarios where computational resources are constrained or network connectivity is limited.

(8) What is needed is a system that can efficiently leverage the reasoning capabilities of large language models while reducing computational overhead. Such a system should be able to cache and reuse model reasoning patterns, extend effective context beyond traditional limits, and maintain the quality of responses while significantly reducing resource requirements. Additionally, the system should provide flexibility in deploying these capabilities across both local and cloud-based architectures while enabling knowledge sharing across users when appropriate.

SUMMARY OF THE INVENTION

(9) The inventor has developed a system and method for a multi-state LLM with unlimited context. This invention presents an efficient system for language model operation that combines large and small language models with a sophisticated thought caching architecture. At its core, the system uses a large language model to generate “thoughts”-intermediate reasoning steps about prompts-which can then be cached and reused. These thoughts, along with the original prompts, are processed through a smaller, more efficient language model to generate responses. The system includes a router that can either direct prompts to the large model for new thought generation or retrieve relevant thoughts from a cache, eliminating the need to regenerate similar reasoning patterns for related prompts. A controller manages thought quality and cache operations, while a thought synthesizer can combine multiple cached thoughts to create new ones when necessary. The architecture supports both local and cloud-based caching, enabling thoughts to be shared across devices and users while maintaining efficiency through edge computing. By employing Multi-head Latent Attention (MLA) mechanisms, the system achieves significant reductions in key-value cache requirements during inference while maintaining or improving performance compared to traditional attention mechanisms. This approach substantially reduces computational overhead while maintaining response quality, effectively extending context windows beyond traditional limits and enabling efficient scaling across different deployment scenarios.

(10) A system and method for data compression with genomic encryption, which uses frequency analysis on data blocks within an input data stream to produce a prefix table, representing a first layer of transformation, and which applies a Burrow's-Wheeler transform (BWT) to the data inside the prefix table, representing a second layer of transformation, and which compresses the transformed data. In some implementations, the system and method may further include applying the BWT to a conditioned stream of genomic data, wherein the conditioned stream of genomic data is accompanied by an error stream comprising the differences between the original data and the encrypted data.

(11) According to a preferred embodiment, a computer system comprising a hardware memory, wherein the computer system is configured to execute software instructions stored on nontransitory machine-readable storage media that: receive a prompt from a user; process the prompt into a plurality of corresponding thoughts using a first large language model; route both the prompt and the plurality of thoughts through a second large language model that has fewer parameters than the first large language model; associate each corresponding thought in the plurality of corresponding thoughts to a portion of the prompt; cache each associated corresponding thought, wherein a plurality of associated corresponding thoughts may be retrieved from a thought cache when the portion of the prompt they correspond to is present in a future prompt; and generate a response to the prompt by processing the plurality of thoughts and the prompt through the second large language model, is disclosed.

(12) According to another preferred embodiment, a method for encrypted data compression with a hardware management layer, comprising the steps of: receiving a prompt from a user; processing the prompt into a plurality of corresponding thoughts using a first large language model; routing both the prompt and the plurality of thoughts through a second large language model that has fewer parameters than the first large language model; associating each corresponding thought in the plurality of corresponding thoughts to a portion of the prompt; caching each associated corresponding thought, wherein a plurality of associated corresponding thoughts may be retrieved from a thought cache when the portion of the prompt they correspond to is present in a future prompt; and generating a response to the prompt by processing the plurality of thoughts and the prompt through the second large language model, is disclosed.

(13) According to an aspect of an embodiment, the computer system is further configured to execute software instructions stored on nontransitory machine-readable storage media that: analyzing the prompt using a prompt analyzer to determine key concepts and requirements;

querying the thought cache to determine if similar thoughts exist for the determined key concepts; and synthesizing new thoughts when similar thoughts exist but do not fully address the prompt requirements.

(14) According to an aspect of an embodiment, the thought cache comprises at least a local cache stored on an edge device and a global cache stored in a cloud environment, wherein the global cache is accessible by a plurality of edge devices.

(15) According to an aspect of an embodiment, the global cache is organized into specialized domains, and thoughts are categorized and stored according to their relevant domain.

(16) According to an aspect of an embodiment, caching each associated corresponding thought comprises: evaluating relevance of the thought to the portion of the prompt; assigning metadata tags based on the evaluation; storing the thought with vector embeddings for similarity searching; and indexing the thought for retrieval.

Description

BRIEF DESCRIPTION OF THE DRAWING FIGURES

(1) The accompanying drawings illustrate several aspects and, together with the description, serve to explain the principles of the invention according to the aspects. It will be appreciated by one skilled in the art that the particular arrangements illustrated in the drawings are merely exemplary, and are not to be considered as limiting of the scope of the invention or the claims herein in any way.

(2) FIG. 1 (Prior Art) is a block diagram illustrating a common transformer architecture used in most large language models.

(3) FIG. 2 is a block diagram illustrating an exemplary architecture for a latent transformer, where the transformer operates on latent space vector representations of an input.

(4) FIG. 3 is a block diagram illustrating an exemplary system architecture for a multi-state LLM with unlimited context.

(5) FIG. 4 is a block diagram illustrating an exemplary system architecture for a multi-state LLM with unlimited context with thought synthesis and retrieval.

(6) FIG. 5 is a block diagram illustrating an exemplary system architecture for a multi-state LLM with unlimited context with local and global thought caches.

(7) FIG. 6 is a block diagram illustrating exemplary components for a multi-state LLM with unlimited context, a router and a controller.

(8) FIG. 7 is a flow diagram illustrating an exemplary method for natural language processing using a dual-model approach with thought generation.

(9) FIG. 8 is a flow diagram illustrating an exemplary method for thought creation, evaluation, and storage within the system.

(10) FIG. 9 is a flow diagram illustrating an exemplary method for synchronizing thought caches between local devices and a global cloud environment.

(11) FIG. 10 is a block diagram illustrating an exemplary system architecture of a thought cache that has both a long-term memory and a short-term memory.

(12) FIG. 11 illustrates an exemplary computing environment on which an embodiment described herein may be implemented.

DETAILED DESCRIPTION OF THE DRAWING FIGURES

(13) The inventor has conceived, and reduced to practice, system and method for a multi-state LLM with unlimited context. This invention presents a novel system for efficient language model operation that combines the reasoning capabilities of large language models with the computational efficiency of smaller models. The system utilizes a unique architecture where prompts are first processed by a large language model to generate “thoughts”-intermediate reasoning steps that

capture the model's analysis and understanding. These thoughts can be cached and reused, eliminating the need to regenerate similar reasoning patterns for related prompts. Through the use of Multi-head Latent Attention (MLA) mechanisms, the system achieves significant reductions in key-value cache requirements during inference while maintaining or improving performance compared to traditional attention mechanisms. The system employs a router that can direct prompts either through the large model for new thought generation or retrieve relevant thoughts from a cache, which are then processed by a smaller, more efficient model to generate responses.

(14) The system's architecture includes components for thought management and optimization. A controller oversees thought quality and cache operations, employing multiple evaluation criteria to ensure cached thoughts maintain their utility and relevance. A thought synthesizer can combine multiple related thoughts to create new ones, using various combination strategies depending on the relationship between thoughts and the specific requirements of the prompt. The system implements a distributed caching architecture that enables both local and cloud-based storage of thoughts, with sophisticated synchronization mechanisms to maintain coherence between different cache levels. This approach significantly reduces computational overhead while maintaining response quality, effectively extending context windows beyond traditional limits by converting context history into cached thoughts that can be retrieved as needed. The system supports various deployment scenarios, from edge devices with local caching to cloud-based deployments with shared knowledge bases, making it highly versatile for different applications. In an embodiment, the architecture includes components such as a prompt analyzer for breaking down input requirements, a cache query interface for efficient thought retrieval, and a model selector for optimizing resource utilization. Through these mechanisms, the system substantially reduces the computational resources required for language model operation while maintaining the sophisticated reasoning capabilities typically associated with much larger models.

(15) One or more different aspects may be described in the present application. Further, for one or more of the aspects described herein, numerous alternative arrangements may be described; it should be appreciated that these are presented for illustrative purposes only and are not limiting of the aspects contained herein or the claims presented herein in any way. One or more of the arrangements may be widely applicable to numerous aspects, as may be readily apparent from the disclosure. In general, arrangements are described in sufficient detail to enable those skilled in the art to practice one or more of the aspects, and it should be appreciated that other arrangements may be utilized and that structural, logical, software, electrical and other changes may be made without departing from the scope of the particular aspects. Particular features of one or more of the aspects described herein may be described with reference to one or more particular aspects or figures that form a part of the present disclosure, and in which are shown, by way of illustration, specific arrangements of one or more of the aspects. It should be appreciated, however, that such features are not limited to usage in the one or more particular aspects or figures with reference to which they are described. The present disclosure is neither a literal description of all arrangements of one or more of the aspects nor a listing of features of one or more of the aspects that must be present in all arrangements.

(16) Headings of sections provided in this patent application and the title of this patent application are for convenience only, and are not to be taken as limiting the disclosure in any way.

(17) Devices that are in communication with each other need not be in continuous communication with each other, unless expressly specified otherwise. In addition, devices that are in communication with each other may communicate directly or indirectly through one or more communication means or intermediaries, logical or physical.

(18) A description of an aspect with several components in communication with each other does not imply that all such components are required. To the contrary, a variety of optional components may be described to illustrate a wide variety of possible aspects and in order to more fully illustrate one or more aspects. Similarly, although process steps, method steps, algorithms or the like may be

described in a sequential order, such processes, methods and algorithms may generally be configured to work in alternate orders, unless specifically stated to the contrary. In other words, any sequence or order of steps that may be described in this patent application does not, in and of itself, indicate a requirement that the steps be performed in that order. The steps of described processes may be performed in any order practical. Further, some steps may be performed simultaneously despite being described or implied as occurring non-simultaneously (e.g., because one step is described after the other step). Moreover, the illustration of a process by its depiction in a drawing does not imply that the illustrated process is exclusive of other variations and modifications thereto, does not imply that the illustrated process or any of its steps are necessary to one or more of the aspects, and does not imply that the illustrated process is preferred. Also, steps are generally described once per aspect, but this does not mean they must occur once, or that they may only occur once each time a process, method, or algorithm is carried out or executed. Some steps may be omitted in some aspects or some occurrences, or some steps may be executed more than once in a given aspect or occurrence.

(19) When a single device or article is described herein, it will be readily apparent that more than one device or article may be used in place of a single device or article. Similarly, where more than one device or article is described herein, it will be readily apparent that a single device or article may be used in place of the more than one device or article.

(20) The functionality or the features of a device may be alternatively embodied by one or more other devices that are not explicitly described as having such functionality or features.

(21) Thus, other aspects need not include the device itself.

(22) Techniques and mechanisms described or referenced herein will sometimes be described in singular form for clarity. However, it should be appreciated that particular aspects may include multiple iterations of a technique or multiple instantiations of a mechanism unless noted otherwise. Process descriptions or blocks in figures should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process. Alternate implementations are included within the scope of various aspects in which, for example, functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those having ordinary skill in the art.

Definitions

(23) As used herein, “thought” refers to a discrete unit of reasoning or analysis generated by a large language model during its processing of an input prompt. A thought represents the model's intermediate reasoning steps, analysis, or considerations about the prompt before generating a final response. Thoughts are generated during a reasoning phase of the model's operation and contain the model's understanding, context analysis, and logical processing of the prompt. Unlike raw text or embeddings, thoughts encapsulate the model's processed reasoning in a form that can be cached, retrieved, and reused for similar prompts. Thoughts may be explicitly visible in model outputs or may be internally generated, and can be stored in various cache architectures including local and cloud-based systems. These cached thoughts can be combined with new prompts to generate responses using smaller language models, effectively preserving the reasoning capabilities of larger models while reducing computational overhead.

(24) As used herein, “context” refers to both traditional sequence-based context where a language model processes a series of tokens representing prior interactions or information, and thought-based context where the model processes higher-level abstractions in the form of thought sequences. Traditional context operates at the token level, maintaining a history of specific words, phrases, and their relationships through mechanisms like attention windows. In contrast, thought-based context operates at a higher level of abstraction, where each thought represents a complex unit of reasoning or understanding. This dual nature of context allows the system to maintain contextual awareness both through detailed token-level information and through more abstract

thought-level representations, enabling efficient processing of complex interactions while reducing the computational overhead typically associated with maintaining long token sequences. Thought-based context can compress what would traditionally require thousands of tokens into a smaller number of thought units, each capturing key reasoning patterns and conceptual relationships relevant to the interaction.

(25) Conceptual Architecture

(26) FIG. 1 (Prior Art) is a block diagram illustrating a common transformer architecture used in most large language models. A transformer generally comprises an encoder (the components on the left side of the illustration) and a decoder (the components on the right side of the illustration).

(27) The illustrated transformer comprises an encoder and a decoder. The encoder takes input embeddings and processes them through a stack of layers (represented as dashed box **130**). Each layer consists of: positional encoding, which adds position information to the input embeddings; multi-head attention, which allows the model to attend to different parts of the input sequence; add and norm, which applies residual connection and layer normalization; feed forward, which is a fully connected feed-forward network; and add and norm which is another residual connection and layer normalization.

(28) The power of the transformer model lies in the self-attention mechanism. This mechanism contributes to accelerated learning compared to traditional models such as long short-term memory models. Self-attention empowers the transformer model with the remarkable capability to meticulously scrutinize distinct segments of a given sequence or even encompass the entire contextual essence of a sentence. This profound contextual awareness enables the model to make predictions with an elevated degree of accuracy and relevance.

(29) The transformer takes a processed vector as its input **100**. The input embedding **120** to the encoder is a sequence of tokens, typically represented as integers. Each token is mapped to a learnable embedding vector of a fixed size. The embedding layer is a lookup table that converts each token into its corresponding dense vector representation. The embeddings are learned during training and capture semantic and syntactic relationships between tokens.

(30) A dense vector representation, also known as a dense embedding or a continuous vector representation, is a way of representing data, particularly words or tokens, as dense vectors in a high-dimensional continuous space. In the context of natural language processing (NLP) and language models, dense vector representations are used to capture semantic and syntactic information about words or tokens. Each word or token is mapped to a fixed-size vector of real numbers, typically with hundreds or thousands of dimensions. Each word or token is represented by a vector of a fixed size, regardless of the length of the input sequence. The size of the vector is a hyperparameter that is determined during model design. The vectors exist in a continuous high-dimensional space, where each dimension represents a latent feature or aspect of the word or token. The continuous nature allows for capturing fine-grained relationships and similarities between words. The dense vector representations are learned during the training process of the model. The model learns to assign similar vectors to words that have similar meanings or occur in similar contexts. The dense vector representations aim to capture semantic and syntactic relationships between words. Words that have similar meanings or are used in similar contexts tend to have similar vector representations. Dense vector representations allow for performing algebraic operations on words, such as addition and subtraction. These operations can capture analogies and relationships between words, such as “prince”-“man”+“woman”~“princess”. Dense vector representations serve as input features for various downstream NLP tasks, such as text classification, sentiment analysis, named entity recognition, and machine translation. The dense representations provide a rich and informative input to the models, enabling them to learn patterns and make predictions. Some popular examples of dense vector representations include, but are not limited to, Word2Vec, Global Vectors for Word Representations (GloVe), FastText, and BERT.

(31) After the input embedding layer, positional encoding **110** is added to the input embedding to

provide position information to the model. Since the Transformer architecture doesn't have inherent recurrence or convolution, positional encodings help capture the order and relative positions of tokens. The positional encodings are typically sine and cosine functions of different frequencies, allowing the model to learn relative positions. The positional encodings have the same dimensionality as the input embeddings and are summed with them.

(32) The encoder utilizes a multi-head attention mechanism **131** which is a key component of the transformer architecture. It allows the encoder to attend to different parts of the input sequence and capture dependencies between tokens. The attention mechanism computes three matrices: query (Q), key (K), and value (V). The query, key, and value matrices are obtained by linearly projecting the input embeddings using learned weight matrices. The attention scores are computed by taking the dot product of the query matrix with the transpose of the key matrix, followed by scaling and applying a softmax function. The attention scores determine the importance of each token in the input sequence for a given position. The value matrix is then multiplied with the attention scores to obtain the weighted sum of the values, which forms the output of the attention mechanism. Multi-head attention splits the query, key, and value matrices into multiple heads, allowing the model to attend to different aspects of the input simultaneously. The outputs from each head are concatenated and linearly projected to obtain the final output of the multi-head attention layer **131**.

(33) After the multi-head attention layer, a residual connection is applied, followed by layer normalization at add and norm **140**. The residual connection adds the input embeddings to the output of the attention layer, helping the model learn faster and deeper. Layer normalization normalizes the activations across the features, stabilizing the training process.

(34) While traditional multi-head attention mechanisms contributes to accelerated learning compared to models like LSTMs, innovations like multi-head Latent Attention (MLA) further enhance efficiency through low-rank key-value joint compression. MLA achieves this by compressing the key-value pairs into a latent vector, significantly reducing the key value cache required during inference while maintaining or improving performance compared to standard multi-head attention mechanism. The attention mechanism still empowers the model to scrutinize distinct segments of sequences, but MLA does so while requiring only a fraction of the computational resources

(35) The feed forward layer **150** is a fully connected neural network applied to each position of the encoder's hidden states. It consists of two linear transformations with a Rectified Linear Unit (ReLU) activation function in between. The purpose of the feed forward **150** layer is to introduce non-linearity and increase the model's capacity to learn complex representations. The output of the feed forward **150** layer has the same dimensionality as the input embeddings. A residual connection and layer normalization **140** are applied after the feed forward **150** layer.

(36) The encoder layers **130** are stacked $N \times$ times, where N is a hyperparameter that determines the depth of the Encoder. Each layer follows the same structure: multi-head attention, add & norm, feed forward, and add & norm. By stacking multiple encoder layers, the model can capture hierarchical and long-range dependencies in the input sequence. The output of the final encoder layer represents the encoded input sequence, which is then passed to the decoder for generating the output sequence.

(37) The decoder generates the output probabilities. It has a similar structure to the Encoder, with a few additions. The decoder takes output embeddings and processes them through a stack of layers (represented as dashed box **160**). The output embedding layer **170** takes the previous processed input tokens (shifted right by one position) and converts them into dense vectors. Each token is mapped to a learnable embedding vector of a fixed size. The embedding vectors capture semantic and syntactic relationships between tokens.

(38) Positional encoding **180** is added to the output embedding **170** to provide position information to the model. Since the transformer architecture does not have inherent recurrence or convolution, positional encodings help capture the order and relative positions of tokens. The positional

encodings are typically sine and cosine functions of different frequencies, allowing the model to learn relative positions.

(39) The masked multi-head attention **161** mechanism prevents the model from attending to future tokens. This layer performs self-attention on the decoder's input sequence. It allows the decoder to attend to different parts of its own input sequence. The attention is “masked” to prevent the decoder from attending to future tokens, ensuring that the predictions are based only on the previously generated tokens. Multi-head attention splits the input into multiple heads, allowing the model to attend different aspect of the input simultaneously.

(40) After the masked multi-head attention, a residual connection is applied followed by layer normalization via add and norm **140**. The residual connection adds the input to the output of the attention layer, helping the model learn faster and deeper. Layer normalization normalizes the activations across the features, stabilizing the training process.

(41) The multi-head attention **131** layer performs attention between the decoder's hidden states and the encoder's output. It allows the decoder to attend to relevant parts of the input sequence based on the encoder's representations. The attention weights are computed based on the compatibility between the Decoder's hidden states and encoder's outputs.

(42) Another add and norm **140** layer is then followed by feed forward network **150**. This a fully connected feed-forward network applied to each position of the decoder's hidden states. It consists of two linear transformations with a Rectified Linear Unit (ReLU) activation in between. The feed forward layer helps the model capture non-linear interactions and increases the model's capacity.

(43) Another add and norm **140** layer is followed by linear **191** and softmax **192** layers. The final hidden states of the decoder are passed through a linear transformation to project them into the vocabulary space. Vocabulary space refers to the set of all unique tokens or words that the model can generate or predict. In the context of language models, the vocabulary is a predefined set of tokens that the model is trained on and can output. When the decoder's final hidden states are passed through a linear transformation, they are projected into a vector space with the same dimensionality as the size of the vocabulary. Each dimension in this space corresponds to a specific token in the vocabulary. For example, the model has a vocabulary of 10,000 unique tokens. The linear transformation would project the decoder's hidden states into a 10,000-dimensional vector space. Each element in this vector represents the model's predicted probability or score for the corresponding token in the vocabulary.

(44) A softmax function is applied to the projected values (vectors) to generate output probabilities over the vocabulary. The softmax function normalizes the values so that they sum up to 1, representing a probability distribution over the vocabulary. Each probability indicates the likelihood of a specific token being the next output token. The token with the highest probability is selected as the next output token. During the model's training, the objective is to maximize the probability of the correct next token given the input sequence and the previously generated tokens. The model learns to assign higher probabilities to the tokens that are more likely to appear based on the context. At inference time, the token with the highest probability in the vocabulary space is selected as the next output token. This process is repeated iteratively, with the generated token being fed back into the decoder as input for the next step, until a stopping criterion is met (e.g., reaching a maximum length or generating an end-of-sequence token). The size and composition of the vocabulary can vary depending on the specific task and the data the model is trained on. It can include words, sub-words, or even characters, depending on the tokenization strategy used.

(45) The decoder layers **160** can be stacked Nx times, allowing the model to capture complex dependencies and generate coherent output sequences.

(46) This transformer architecture allows the model to process input sequences, capture long-range dependencies, and generate output sequence based on the encoded input and the previously generated tokens.

(47) There are at least three variations of transformer architecture that may enable an LCM. A first

such variation comprises Auto-Encoding Models. In autoencoders, the decoder portion of the transformer is discarded after pre-training and only the encoder is used to generate the output. The popular BERT and ROBERTa models are examples of models based on this architecture and perform well on sentiment analysis and text classification. These types of models may be trained using a process called masked language modeling (MLM).

(48) The primary goal of an autoencoder is to learn efficient representations of input data by encoding the data into a lower-dimensional space and then reconstructing the original data from the encoded representation. Autoencoders are trained in an unsupervised manner, meaning they don't require labeled data. They learn to capture the underlying structure and patterns in the input data without explicit guidance. An autoencoder consists of two main components: an encoder and a decoder. The encoder takes the input data and maps it to a lower-dimensional representation, often referred to as the latent space or bottleneck. The decoder takes the latent representation and tries to reconstruct the original input data. Autoencoders can be used for dimensionality reduction by learning a compressed representation of the input data in the latent space. The latent space has a lower dimensionality than the input data, capturing the most salient features or patterns. The training objective of an autoencoder is to minimize the reconstruction error between the original input and the reconstructed output. The model learns to encode and decode the data in a way that preserves the essential information needed for reconstruction.

(49) Variants and extensions of autoencoders can include denoising autoencoders, variational autoencoders (VAEs) which introduce a probabilistic approach to autoencoders wherein they learn a probabilistic encoder and decoder, allowing for generating new samples from the learned latent space, and conditional autoencoders which incorporate additional conditions or labels as input to the encoder and decoder, enabling the generation of samples conditioned on specific attributes.

(50) Autoencoders can have various applications. Autoencoders can be used to detect anomalies by measuring the reconstruction error. Anomalous samples tend to have higher reconstruction errors compared to normal samples. Autoencoders can be used as a pre-training step to learn meaningful features from unlabeled data. The learned features can then be used for downstream tasks like classification or clustering. Additionally, or alternatively, autoencoders, particularly VAEs, can be used as generative models to generate new samples similar to the training data by sampling from the learned latent space. It's worth noting that while autoencoders can be effective for certain tasks, they have some limitations. They may struggle to capture complex dependencies and may generate blurry or less sharp reconstructions compared to other generative models like Generative Adversarial Networks (GANs).

(51) Another type of variation is the auto-regressive model which feature the use of only the decoder portion of the transformer architecture. In autoregressive architectures, the decoder portion of the transformer is retained and the encoder portion is not used after model pre-training. Auto-regressive models are a class of models that generate outputs by predicting the next element based on the previously generated elements. In the context of the Transformer architecture and language modeling, auto-regressive models are commonly used for tasks such as text generation, machine translation, and language understanding.

(52) Auto-regressive models generate outputs sequentially, one element at a time. In the case of language modeling, the model predicts the next word or token based on the previous words or tokens in the sequence. The prediction of the next element is conditioned on the previously generated elements. The model learns the conditional probability distribution $P(x_t | x_1, x_2, \dots, x_{t-1})$, where x_t is the element at position t , and x_1, x_2, \dots, x_{t-1} are the previously generated elements. The transformer architecture, particularly the decoder component, is well-suited for auto-regressive modeling. The decoder generates the output sequence one element at a time, conditioned on the previously generated elements and the encoded input sequence from the encoder. In the transformer decoder, the self-attention mechanism is masked to prevent the model from attending to future positions during training. This masking ensures that the model relies only

on the previously generated elements to make predictions, following the auto-regressive property. During training, the transformer decoder uses a technique called teacher forcing. Instead of feeding the model's own predictions as input for the next step, the ground truth target sequence is used. This helps the model learn to generate the correct output sequence based on the input sequence and the previous target tokens. During inference or generation, the transformer decoder generates the output sequence one element at a time. At each step, the model takes the previously generated elements as input and predicts the next element. This process continues until a stopping criterion is met, such as reaching a maximum sequence length or generating an end-of-sequence token. Auto-regressive models, including the transformer, have achieved state-of-the-art performance in language modeling tasks. They excel at capturing the statistical properties and dependencies in sequential data, making them effective for generating coherent and fluent text.

(53) While text generation is the most suitable use case of auto-regressors, they perform exceptionally well on a wide variety of tasks. Most modern LLMs are auto-regressors including, for example, the popular GPT series of LLMs, BERT, and XLNet.

(54) The third variation of the transformer model is the sequence-to-sequence model which utilizes both the encoder and decoder portions of the transformer and can be trained in multiple ways. One of the methods is span corruption and reconstruction. These models are, generally, best suited for language translation. The T5 and BART family of models are examples of sequence-to-sequence models.

(55) FIG. 2 is a block diagram illustrating an exemplary architecture for a latent transformer, where the transformer operates on latent space vector representations of an input. Central to a latent transformer is a latent transformer subsystem **220**, which serves as the central processing unit responsible for learning the underlying patterns, relationships, and dependencies within the input data. Latent transformer subsystem **220** leverages advanced techniques such as self-attention mechanisms and multi-head attention to capture the complex interactions and sequences in the data, enabling it to generate accurate and context-aware outputs.

(56) The input to latent transformer subsystem **220** is provided by a VAE (Variational Autoencoder) encoder subsystem **200**. VAE encoder subsystem **600** is responsible for encoding an input into a lower-dimensional latent space representation. VAE encoder subsystem **200**, learns to compress the data into a compact latent space representation while preserving the essential features and characteristics of the input. Latent space vectors produced by the VAE encoder subsystem **200** may be further processed by an expander **210**, which increases the dimensionality of the input data to a point where the vectors can be efficiently processed by latent transformer subsystem **220**.

(57) A latent space representation of the input generated by VAE encoder subsystem **200** serves as the input to latent transformer subsystem **220**. Latent transformer subsystem **220** operates in this latent space, leveraging the compressed and informative representation to learn the complex patterns and relationships within the data. By working in the latent space, latent transformer subsystem **220** can efficiently process and model the data, capturing the intricate dependencies and generating accurate and meaningful outputs.

(58) Once latent transformer subsystem **220** has processed the latent space representation, the generated output is passed through a VAE decoder subsystem **240**. VAE decoder subsystem **240** is responsible for decoding the latent space representation back into the original data space. Prior to processing by VAE decoder subsystem **240**, latent transformer subsystem **220** outputs may be compressed back to an original size before being processed by the expander **210** by being processed by a compressor **230**. VAE decoder subsystem **240** learns to reconstruct the original data from the latent space representation, ensuring that the generated output is coherent and meaningful.

(59) The reconstructed output from VAE decoder subsystem **240** is provided as a compressed generated output **250**. The compressed generated output **250** represents the final result of the latent transformer, which is a compressed version of the original input.

(60) VAE encoder subsystem **200** and VAE decoder subsystem **240** play large roles in the overall

functioning of the latent transformer. VAE encoder subsystem **200** enables the system to learn a compressed and informative representation of the input data in the latent space, while the VAE decoder subsystem **240** ensures that the compressed generated output **250** is coherent and meaningful by reconstructing it back into the original data space. The combination of these subsystems allows the latent transformer to focus on learning the complex patterns and relationships within the data, leading to accurate and context-aware outputs.

(61) The specific architectures and parameters of VAE encoder subsystem **200**, latent transformer subsystem **220**, and VAE decoder subsystem **240** can be customized and adapted based on the characteristics and requirements of the input data and the specific task at hand. The modular design of the system allows for flexibility and extensibility, enabling the integration of different architectures, attention mechanisms, and training techniques to optimize the performance and efficiency of the latent transformer.

(62) FIG. 3 is a block diagram illustrating an exemplary system architecture for a multi-state LLM with unlimited context. The system includes a large language model **300**, a router **310**, a controller **360**, a thought cache **370**, and a smaller language model **340** that work together to process prompts and generate responses while optimizing computational resources.

(63) The system receives an initial prompt (P) **320** through the router **310**. The router serves as the central control component, determining whether to utilize the large language model **300** or access the thought cache **370** through the controller **360**. Upon receiving a prompt, the router first queries the thought cache to determine if relevant thoughts exist for similar prompts.

(64) The large language model **300** includes an input component **301**, an encoder **302**, a decoder **303**, and an output generator **304**. The large language model **300** can utilize various internal architectures, including but not limited to traditional transformer cores (as shown in FIG. 1) or latent transformer cores (as shown in FIG. 2). The model's attention mechanisms can be implemented using either standard multi-head attention (MHA) or multi-head latent attention (MLA), with the overall system functioning identically regardless of the specific attention mechanism chosen. When using MLA, the model benefits from reduced KV cache requirements during inference while maintaining performance comparable to or better than traditional MHA implementations. When the router determines that cached thoughts are not available or suitable, the prompt is processed through the large language model **300**. During this processing, the model enters a reasoning phase where it generates thoughts (T) **321** about the prompt. These thoughts represent the model's analysis and reasoning about the prompt before generating a final response.

(65) The controller **360** manages interaction with the thought cache **370**, which can be implemented as either a local or cloud-based storage system. The thought cache stores previously generated thoughts in a vector database format, allowing for efficient retrieval of relevant thoughts for similar prompts. The cache can maintain both session-specific thoughts for temporary storage and long-term thoughts for persistent knowledge.

(66) When thoughts are either generated by the large language model or retrieved from the cache, they are combined with the original prompt to create a prompt and thought combination (P+T) **330**. This combination is then routed to the smaller language model **340**, which requires significantly fewer computational resources than the large model. The smaller model processes the P+T **330** combination to generate the final response **350**.

(67) In operation, for example, if a user submits a prompt asking about climate change impacts, the router first checks the thought cache for relevant existing thoughts. If suitable thoughts exist, they are retrieved and combined with the prompt. If no relevant thoughts are found, the large model processes the prompt to generate new thoughts about climate science, global impacts, and relevant data. These thoughts, combined with the original prompt, are then processed by the smaller model **340** to generate a concise, relevant response. The new thoughts are also cached for future use. To demonstrate how thoughts are created, imagine the prompt "What do you think is the future of string theory, particularly given the spectacular failure of supersymmetry at LHC" being entered

into the LLM DeepSeek. During the reasoning phase, the model returns to the user the following thoughts:

- (68) “Okay, the user is asking about the future of string theory in light of supersymmetry not being found at the LHC. Let me start by recalling what I know about string theory and SUSY.
- (69) String theory relies heavily on supersymmetry because SUSY helps stabilize the extra dimensions and makes the math work better. But the LHC hasn't found any superpartners, which challenges some of the more popular SUSY models. However, I should note that SUSY isn't the only part of string theory. There are versions without it, like bosonic string theory, but those aren't as developed or realistic.
- (70) The user might be implying that since SUSY isn't found, string theory is in trouble. I need to address that but also explain why it's not the whole story. Maybe mention that SUSY could still exist at higher energy scales beyond LHC's reach. Also, string theory has other applications beyond particle physics, like in condensed matter or quantum gravity.
- (71) I should break down the response into points. First, clarify the relationship between SUSY and string theory. Then discuss the LHC results and their implications. Talk about other areas where string theory contributes, like holography or black hole physics. Mention alternatives within string theory that don't rely on low-energy SUSY. Also, touch on the possibility of future experiments or theoretical breakthroughs.
- (72) Need to be balanced. Acknowledge the challenges but also the potential. Avoid being too dismissive or overly optimistic. Maybe conclude by saying the future is uncertain but still active in different areas. Check if there are recent developments post-LHC that I should consider, but since the user didn't specify, stick to general points.
- (73) Make sure to explain technical terms like “landscape” or “holography” briefly. Keep the language accessible but precise. The user might be someone with a basic understanding of physics, possibly a student or enthusiast. They want to know if string theory is still viable and where it's headed. They might also be interested in how scientific theories adapt when experimental evidence is lacking.
- (74) In summary, structure the answer to address the SUSY issue, discuss other aspects of string theory, mention alternative research directions, and conclude with the ongoing relevance despite challenges. Ensure each point flows logically and answers the user's concern about the theory's future post-LHC results.” Using the above generated thoughts, model generated a response to the user's query.
- (75) The above thoughts represent T in the accompanying FIG. 3. By extracting thoughts generated by a model in their reasoning phase and passing both those thoughts and the initial prompt through a substantially smaller model with less parameters, the same response may be given while using much less energy.
- (76) The system supports multiple cache architectures, including but not limited to local device storage for personal use and cloud-based storage for enterprise applications. This allows for knowledge sharing across users while maintaining appropriate privacy and access controls. Multiple specialized caches can exist for different domains or use cases, such as financial analysis or scientific research.
- (77) The system supports multiple specialized cache architectures that enable domain-specific knowledge storage and AI agent collaboration. These architectures include but are not limited to local device caches for personal use, edge caches for specific AI agents, and distributed cloud-based caches for enterprise applications. Each specialized cache maintains its own thought organization optimized for its domain—for instance, a financial analysis cache might structure thoughts around market patterns and risk assessment frameworks, while a scientific research cache might organize thoughts based on experimental methodologies and theoretical frameworks. AI agents can be assigned primary affinity to specific specialized caches while maintaining ability to access other caches when needed. For example, a financial analysis agent might primarily interact

with the financial cache but could access the scientific research cache when analyzing biotechnology investments. The system implements cache-specific validation rules and quality metrics tailored to each domain's requirements—financial thoughts might require numerical accuracy validation, while scientific thoughts might undergo peer-review-style verification by other AI agents. These specialized caches can operate independently or in interconnected hierarchies, with bridge agents managing thought transfer between different domains. Enterprise deployments can maintain multiple parallel specialized caches with varying access levels, enabling selective knowledge sharing while preserving security boundaries. For instance, a pharmaceutical company might maintain separate but interconnected caches for public research, proprietary development, and regulatory compliance, with AI agents navigating these boundaries based on clearance levels and task requirements.

(78) The system achieves effectively unlimited context windows through a combination of thought abstraction and hierarchical memory management. Rather than attempting to maintain extended token sequences, the system is capable of converting contextual information into thought representations that capture higher-level patterns and relationships. These thoughts serve as compressed encodings of context, where each thought unit may encapsulate understanding that would traditionally require thousands of tokens to represent.

(79) In one embodiment, the system implements a multi-tier thought storage architecture where context exists simultaneously at multiple levels of abstraction. The most recent context maintains detailed thought representations with full fidelity, while older context is progressively synthesized into more abstract thought patterns that capture essential relationships and understanding while reducing storage requirements. This progressive abstraction allows the system to maintain effectively unlimited context while managing computational resources efficiently.

(80) When processing new prompts, router **310** analyzes both recent detailed thoughts and older abstract thoughts to identify relevant context. A thought synthesizer **430** can then combine these different levels of abstraction to generate new thoughts that incorporate both immediate context and long-term understanding. This multi-level synthesis enables the system to maintain contextual coherence across extended interactions without requiring linear scaling of computational resources.

(81) Thought cache **370** implements indexing structures that maintain temporal relationships between thoughts while enabling efficient retrieval based on relevance. Unlike traditional attention mechanisms that must process entire token sequences, the system can directly access relevant thoughts across any temporal distance through its hierarchical indexing system. This capability allows the model to maintain contextual awareness across arbitrarily long sequences while keeping retrieval costs nearly constant.

(82) In one embodiment, thought cache **370** implements multiple storage tiers that automatically organize thoughts based on their temporal relevance and utilization patterns. In its primary tier, the thought cache maintains recent thoughts with their complete reasoning chains and relationship mappings intact. As these thoughts age within the cache, specialized consolidation mechanisms within the cache combine related thoughts into more efficient meta-thoughts that preserve essential reasoning while reducing storage overhead.

(83) Thought cache **370** monitors access patterns and triggers consolidation events when thought clusters meet specific temporal or utilization thresholds. During these events, thought cache **370** analyzes thought clusters using its built-in synthesis capabilities to generate consolidated meta-thoughts. These meta-thoughts capture insights and relationships from the original thought cluster while requiring significantly less storage space. For example, a sequence of thoughts about various machine learning algorithms might consolidate into a meta-thought capturing their comparative advantages and key implementation considerations.

(84) Intelligence within thought cache **370** adapts consolidation timing based on thought utility metrics. Thought cache **370** tracks each thought's retrieval frequency, synthesis participation, and relationship density with other thoughts. Thoughts demonstrating high utility retain their detailed

form longer, while less frequently accessed thoughts undergo earlier consolidation. This adaptive approach ensures that frequently needed reasoning patterns remain readily available in their most useful form.

(85) Thought cache's **370** hierarchical storage structure spans multiple performance tiers, from high-speed memory for recent and frequently accessed thoughts to more economical storage for consolidated meta-thoughts. Thought cache **370** may migrate thoughts between these tiers based on usage patterns and age, optimizing storage resource utilization while maintaining rapid access to relevant contextual information. This tiered structure enables the cache to efficiently manage large volumes of thoughts while keeping the most pertinent information readily accessible.

(86) Thought cache **370** implements a universal thought representation format that enables consistent interpretation across different language models and reasoning contexts. This standardization occurs through a formal thought schema that defines how reasoning steps, logical relationships, and contextual dependencies are encoded. Each thought contains structured fields for core reasoning components, metadata describing the thought's context and assumptions, and explicit markers for temporal and logical dependencies. This structured format ensures that thoughts remain interpretable regardless of which model originally generated them or which model ultimately consumes them.

(87) Before a cached thought is applied to a new context, the system may perform an automated compatibility analysis. This analysis examines both the structural alignment between the cached thought and the current context, and the semantic applicability of the reasoning pattern. The system maintains model-specific adapters that can transform thoughts between different models' preferred reasoning styles while preserving the core logical structure. These adapters handle variations in formatting, vocabulary, and reasoning granularity, ensuring smooth thought transfer between models with different characteristics.

(88) The cache incorporates a contextual validation layer that assesses thought applicability before reuse. When retrieving a cached thought, this layer examines the current prompt's context against the thought's encoded assumptions and dependencies. If misalignments are detected, the system can automatically generate bridging thoughts that reconcile differences between the cached reasoning and the current context. For example, if a cached mathematical proof assumes certain preconditions that differ slightly from the current problem, the system generates additional reasoning steps to account for these differences.

(89) The system's thought schema includes explicit version controls and model compatibility markers. These markers identify which model versions and architectures have successfully utilized each thought, enabling the cache to predict compatibility issues before attempting thought reuse. When new model versions are deployed, the system can automatically flag thoughts that may require revalidation or adaptation to maintain compatibility with updated model capabilities or knowledge cutoffs.

(90) Through these standardization and compatibility mechanisms, the thought cache ensures reliable thought transfer across different models and contexts while maintaining the integrity of reasoning patterns. The combination of structured thought representation, contextual validation, and adaptive transformation enables efficient thought reuse while preventing inconsistencies or misinterpretations.

(91) Through this architecture, the system achieves effective unlimited context not through brute-force token retention but through intelligent abstraction and synthesis of understanding. The smaller language model can process these thought-based contexts more efficiently than traditional token sequences, enabling contextual reasoning without the computational overhead typically associated with extended context windows.

(92) The system supports multiple architectural approaches for maintaining extended context through thought processing. While transformer-based attention mechanisms provide one implementation path, the system can alternatively employ recurrent neural networks (RNNs) for

processing thought sequences. In an RNN-based implementation, thoughts are processed sequentially, with the network's hidden state maintaining a compressed representation of historical context. This approach enables efficient processing of arbitrary-length thought sequences while maintaining a constant memory footprint, as the hidden state size remains fixed regardless of sequence length.

(93) The system may also implement memory networks for thought storage and retrieval. These networks maintain an explicit, addressable memory that stores thought representations and their relationships. Unlike attention mechanisms that must process all context simultaneously, memory networks can selectively access relevant thoughts through content-based addressing. The memory network architecture enables direct access to specific thoughts based on relevance to the current prompt, without requiring linear scanning of the entire context history.

(94) The thought cache itself can be structured as a differentiable neural memory, where thoughts are stored as embeddings that can be smoothly updated and combined. This approach enables the cache to learn optimal thought storage and retrieval patterns through experience, adapting its organization to maximize the utility of cached thoughts. The differentiable memory structure supports gradient-based optimization of thought storage and retrieval operations, allowing the system to continuously improve its context management efficiency.

(95) Hybrid architectures combining multiple approaches can leverage the strengths of each method. For example, in one embodiment, the system might employ RNNs for sequential thought processing while using a memory network for long-term storage, or combine transformer attention for recent context with compressed RNN states for historical context. These hybrid approaches enable flexible scaling of context processing based on specific application requirements and resource constraints.

(96) FIG. 4 is a block diagram illustrating an exemplary system architecture for a multi-state LLM with unlimited context with thought synthesis and retrieval. The figure demonstrates how the system handles scenarios where cached thoughts may be relevant but not precisely matched to the current prompt.

(97) The system begins when a prompt (P) 320 is received by the router 310. When router 310 receives a prompt 320, it interacts with the thought cache 370 through the controller 360 to retrieve potentially relevant thoughts.

(98) The controller 360 performs two key functions in this embodiment. First, it selects the closest thought (T.sub.0) 400 from the cache that relates to the current prompt. Second, after a synthesizer 430 creates a new thought T.sub.1 410, controller 360 manages the storage of newly synthesized thoughts. The controller evaluates the retrieved T.sub.0 against certain relevance thresholds to determine if synthesis is needed. These thresholds can be configured based on vector similarity scores between the prompt and the cached thought, with different thresholds potentially being set for different domains or use cases. For example, a threshold of 0.8 (on a 0-1 scale) might indicate the thought is relevant enough to use directly, while scores between 0.5-0.8 might trigger synthesis with other related thoughts, and scores below 0.5 might indicate the need to generate entirely new thoughts using the large model. The system can also employ multiple thresholds simultaneously—one for determining if a thought is “close enough” to use directly, another for determining if thoughts are similar enough to be candidates for synthesis, and another for determining if cached thoughts are relevant enough to be considered at all.

(99) The system can assign and append relevance scores and metadata to thoughts in several ways. When a thought (T) is created by the large model, it can be analyzed and scored across multiple dimensions including but not limited to quality assessment metrics, vector embeddings, usage statistics, and domain tags. Quality assessment encompasses the thought's reasoning pattern quality based on its structure and completeness, accuracy scores for verifiable facts, and confidence scores from the model about its conclusions. Vector embeddings can be calculated and stored with each thought, allowing for fast similarity comparisons during cache lookups, with multiple specialized

embeddings potentially stored for different aspects like topic, reasoning style, and domain. Usage statistics track metrics such as success rates when the thought is used (including user feedback), frequency of successful reuse, and performance metrics when used with different types of prompts. Domain tags provide additional context through subject matter categorization, specific topic tags, and required expertise level indicators. These scores and metadata can be stored alongside the thought in the cache in a structured format and updated over time based on usage patterns. The comprehensive metadata enables more sophisticated routing and synthesis decisions while allowing the system to improve its thought selection over time through continuous feedback and performance tracking. For instance, a thought might store its general and domain-specific embeddings, various quality and confidence scores, detailed categorization, and usage statistics, all of which can be used to make more informed decisions about when and how to use or synthesize that thought in future operations.

(100) A synthesizer **360** processes T.sub.0 to create a new thought T.sub.1 that better aligns with the current prompt's requirements. For example, if a prompt asks about specific aspects of quantum computing, and T.sub.0 contains general quantum computing concepts, the synthesizer can create a T.sub.1 that focuses more precisely on the specific aspects requested in the prompt.

(101) Thought synthesizer **430** combines and processes thoughts when multiple relevant thoughts are found or when existing thoughts need modification. For example, if one cached thought covers quantum bits and another covers error correction, the synthesizer can combine these into a new thought that addresses quantum computing error rates in qubits. The synthesizer can also adapt existing thoughts to better match current prompt requirements. This synthesis process involves understanding the logical relationships between different thoughts, identifying complementary and conflicting information, and creating coherent combinations that preserve the accuracy and context of the original thoughts. The synthesizer employs various combination strategies depending on the relationship between thoughts—it might perform simple concatenation for complementary thoughts, create hierarchical structures for nested concepts, or generate entirely new bridging content to connect related ideas. Additionally, the synthesizer can evaluate the quality of synthesized thoughts and may generate multiple candidate combinations before selecting the most appropriate one based on relevance scores and coherence metrics.

(102) The synthesizer can work with multiple retrieved thoughts simultaneously, combining relevant aspects from each to create a more comprehensive T.sub.1. For instance, if one cached thought contains information about neural networks and another about computer vision, the synthesizer could combine relevant aspects of both to create a new thought more specifically targeted to a prompt about neural networks in computer vision applications.

(103) The system may implement multiple strategies for thought synthesis, enabling the combination of existing cached thoughts to generate new, contextually relevant thoughts without necessarily engaging the large language model. These synthesis mechanisms operate on both the semantic content and vector representations of thoughts, employing various combination strategies depending on the relationship between thoughts and specific prompt requirements. The fundamental approach builds upon vector-based synthesis, where thoughts are represented in a high-dimensional embedding space that preserves semantic relationships through spatial relationships. In one embodiment, when multiple relevant thoughts are retrieved from the cache, their vector representations can be combined through a plurality of mathematical operations to create new thought vectors. These operations may include but are not limited to weighted averaging where more relevant thoughts receive higher weights in the final combination, vector addition with normalization that preserves the directional information of component thoughts, dimensional projection where thoughts are combined along specific semantic dimensions while preserving others, and non-linear combination using learned transformation matrices.

(104) The system demonstrates this vector-based synthesis through concrete applications. For instance, when processing a prompt that requires information about quantum computing's impact

on cryptocurrency, and the cache contains separate thoughts about quantum computing (T.sub.1) and cryptocurrency security (T.sub.2), the system performs a weighted combination expressed as $T_{\text{new}} = \alpha * T_1 + \beta * T_2$, where α and β represent relevance weights determined by similarity scores between each thought and the prompt. The resulting vector T_{new} is normalized to maintain consistent magnitude in the embedding space, ensuring that the synthesized thought retains proper proportional representation of its component concepts.

(105) Beyond pure vector operations, the system, in additional embodiments, may employ neural synthesis through a specialized small-scale transformer model trained specifically for thought combination. A neural synthesizer would receive multiple thought vectors as input and generates a new, synthesized thought that captures the relevant aspects of all inputs while maintaining internal consistency. The neural synthesis component is capable of identifying and resolving contradictions between input thoughts, preserving temporal relationships and causal chains, generating bridging content to connect related concepts, and maintaining consistency with the original prompt context. This approach proves particularly valuable when combining thoughts that require subtle understanding of context and implications.

(106) In another embodiment, the system may implement rule-based synthesis through a set of predefined combination patterns based on the logical relationship between thoughts. These patterns support sequential combination for thoughts representing steps in a process, hierarchical combination for thoughts with parent-child relationships, comparative combination for contrasting or parallel thoughts, and supplementary combination for thoughts that provide additional context or examples. The rule-based approach ensures that the structural integrity of thought relationships is preserved during synthesis.

(107) In an embodiment, the system may employ a synthesis quality assessor that evaluates potential thought combinations before they are executed. This assessment examines semantic coherence of the combined thought, preservation of critical information from source thoughts, relevance to the original prompt, and internal consistency of the synthesized thought. The quality assessment process helps prevent the generation and propagation of invalid or inconsistent thought combinations.

(108) In scenarios where multiple synthesis strategies might apply, the system employs a multi-stage synthesis process. This process begins by generating candidate syntheses using different strategies, proceeds to evaluate each candidate using quality metrics, selects the highest-quality synthesis result, and caches the successful synthesis strategy for similar future combinations. This approach ensures optimal synthesis results while building a knowledge base of effective strategies.

(109) The synthesis mechanism supports multiple operation modes including synchronous operation for immediate response requirements, asynchronous operation for background synthesis and cache optimization, and hybrid operation for progressive refinement of synthesized thoughts. This flexibility allows the system to balance response time requirements with synthesis quality needs. Through these synthesis mechanisms, the system can effectively combine and evolve cached thoughts to address new prompts without always requiring the computational overhead of the large language model, while maintaining the quality and relevance of generated responses.

(110) Once T.sub.1 is created, it is combined with the original prompt to form P+T.sub.1 **420**, which is then processed by the smaller language model **340** to generate the final response **350**. The newly synthesized T.sub.1 is also routed back through the controller for potential caching with thought cache **370**, allowing it to be used for future similar prompts.

(111) In one embodiment, thought cache **370** provides performance improvements by eliminating redundant reasoning computations across similar prompts. When **310** router identifies a new prompt with reasoning requirements similar to previously processed queries, thought cache **370** can supply validated thought patterns rather than requiring the large language model to reconstruct the reasoning chain from scratch. This caching mechanism is particularly effective for common analytical patterns, such as mathematical derivations, logical deductions, or standard analytical

frameworks that appear frequently across different prompts.

(112) Additionally, thought cache **370** is capable of serving as a quality assurance mechanism by maintaining verified reasoning patterns. Once a thought sequence has been validated and demonstrates consistent success in generating accurate responses, that sequence becomes a trusted template for handling similar queries. For instance, when processing mathematical problems, the cache may contain verified proof structures that can be applied to new problems within the same class, ensuring consistent and reliable solution approaches.

(113) In one embodiment, thought cache **370** implements a validation scoring system that tracks the success rate and reliability of each cached thought. This scoring considers factors such as but not limited to response accuracy, user feedback, and consistency with known truth standards. Thoughts that consistently contribute to high-quality responses receive higher validation scores, making them more likely to be selected for reuse in similar contexts. The cache can also mark certain thoughts as “golden” references when they demonstrate exceptional reliability in specific domains, establishing them as preferred reasoning patterns for their respective problem types.

(114) To prevent the propagation of incorrect reasoning, thought cache **370** may employ a continuous validation mechanism. This mechanism monitors the performance of cached thoughts and can automatically flag patterns that lead to inconsistent or incorrect responses. When potential issues are detected, thought cache **370** may temporarily suspend the use of problematic thoughts and route similar prompts through the large language model for fresh analysis. This self-correction capability ensures that the efficiency benefits of thought caching do not come at the expense of response quality.

(115) Thought cache **370** is capable of supporting selective thought inheritance, where new prompts can partially inherit validated reasoning patterns while allowing for context-specific modifications. This flexibility enables the system to leverage proven reasoning frameworks while adapting them to specific query requirements, combining the benefits of cached reliability with contextual relevance. Through these mechanisms, the thought cache achieves both performance optimization and quality enhancement, delivering faster responses while maintaining or improving the reliability of the system's outputs.

(116) Through this synthesis process, the system can effectively leverage partially relevant cached thoughts to create more precise and relevant thoughts for the current prompt, reducing the need to engage the large language model while still maintaining response quality and relevance.

(117) In another embodiment, thought cache **370** implements security and privacy controls to protect sensitive information while enabling efficient thought reuse. At the storage level, thought cache **370** maintains isolation between user contexts through encrypted partitioning. Each user's thoughts are encrypted with user-specific keys, ensuring that even within shared cache infrastructure, thoughts remain securely compartmentalized. This encryption extends to both the thought content and the associated metadata, preventing unauthorized access to reasoning patterns that might reveal proprietary information.

(118) In the embodiment, thought cache **370** implements a permissions framework that governs thought sharing and reuse. By default, thoughts derived from user interactions are marked private and restricted to the originating user's context. Users can optionally designate specific thoughts for shared use through explicit consent mechanisms. When thoughts are marked for sharing, the cache employs automated sanitization processes that strip personally identifiable information and sensitive data while preserving the underlying reasoning patterns. This sanitization uses advanced pattern recognition to identify and remove context-specific details while maintaining the thought's utility for general reasoning.

(119) To protect against cache poisoning attacks, thought cache **370** may incorporate a multi-stage validation pipeline. Before any thought is cached, it undergoes verification through a separate validation model that assesses its logical consistency and checks for potential malicious patterns. The cache maintains cryptographic checksums of validated thoughts, enabling rapid verification of

thought integrity during retrieval operations. Additionally, the cache tracks the provenance of each thought, maintaining secure audit trails of thought creation, modification, and usage patterns.

(120) The system implements graduated access controls that can restrict thought reuse based on security clearance levels, organizational boundaries, or specific sharing agreements. These controls allow enterprises to maintain separate thought caches for different security domains while selectively enabling thought sharing under controlled conditions. For instance, a financial institution might maintain separate caches for public customer service interactions and privileged internal analyses, with strict controls governing any cross-domain thought utilization.

(121) Through these security mechanisms, the thought cache enables efficient reasoning reuse while protecting sensitive information and maintaining system integrity. The combination of encryption, access controls, and validation processes ensures that the performance benefits of thought caching do not compromise security or privacy requirements.

(122) FIG. 5 is a block diagram illustrating an exemplary system architecture for a multi-state LLM with unlimited context with local and global thought caches. This embodiment demonstrates how the system can operate primarily on edge devices while maintaining access to a broader knowledge base through cloud connectivity.

(123) Edge device A **500** represents a complete edge implementation of the system, which could be a device such as but not limited to a mobile phone, tablet, or other personal computing device. Within the edge device **500**, router **310** receives prompts (P) **320** and coordinates with a local controller **360** and local cache **510**. Local cache **510** stores frequently accessed or personally relevant thoughts directly on the device, enabling quick access and offline functionality.

(124) The smaller language model **340** runs directly on the edge device, processing prompt and thought combinations **520** to generate responses **350**. This local processing capability significantly reduces latency and computational requirements compared to constantly accessing cloud resources.

(125) The cloud environment **570** contains a global cache **530** managed by a global controller **560**. This global infrastructure serves as a centralized repository for thoughts generated across multiple edge devices (B **540**, C **550**). The global controller coordinates cache synchronization and manages access patterns across the network of connected devices.

(126) When an edge device's controller **360** cannot find relevant thoughts in its local cache **510**, it can query the global controller **560** to search the global cache **530**. For example, if a user on edge device A **500** asks a question about a topic they haven't encountered before, the system first checks the local cache **510**, then can reach out to the global cache **530** for relevant thoughts.

(127) The system supports bi-directional synchronization, where new thoughts generated on edge devices can be uploaded to the global cache, and frequently accessed global thoughts can be downloaded to local caches. This creates a dynamic knowledge-sharing environment while maintaining efficient local operation.

(128) Through this architecture, the system provides the benefits of edge computing (low latency, offline capability, privacy) while maintaining access to a broader knowledge base through the cloud infrastructure. The distributed nature of the system allows for efficient scaling and knowledge sharing across user communities while minimizing the computational load on individual devices.

(129) FIG. 6 is a block diagram illustrating exemplary components for a multi-state LLM with unlimited context, a router and a controller. A prompt analyzer **600** processes incoming prompts to determine their characteristics, domain, and requirements. For example, if a user submits a prompt about quantum computing, the analyzer identifies key technical terms, determines the complexity level, and flags specific concepts that may need specialized thoughts. It also evaluates whether the prompt requires reasoning about multiple concepts (like quantum computing and machine learning) that might benefit from thought synthesis. Analyzer **600** employs natural language processing to break down the prompt into component parts, identifying primary topics, subtopics, relationships between concepts, required depth of knowledge, and any constraints or special requirements specified in the prompt. It can also detect the tone and style of the desired response, technical

sophistication level of the user, and whether the prompt requires factual recall, analytical reasoning, or creative synthesis.

(130) A cache query interface **610** serves as the communication bridge between the router and cache systems. It formats prompt analysis results into efficient cache queries and manages the retrieval process. For instance, when searching for thoughts about quantum computing, it might query both technical definition thoughts and practical application thoughts, managing multiple parallel cache requests to both local and global caches. The interface optimizes query patterns based on the analyzer's output, constructing sophisticated search parameters that account for concept hierarchies, semantic relationships, and contextual relevance. It can prioritize different aspects of the query based on importance, manage query timeouts and fallbacks, and handle distributed cache architectures efficiently. The interface also implements caching strategies to optimize frequent queries and manages cache coherence between local and global storage.

(131) A model selector **620** makes intelligent decisions about model utilization based on cache results and prompt analysis. It implements decision logic to determine whether to: use the large model for new thought generation, proceed with cached thoughts through the smaller model, or employ a hybrid approach. For example, if highly relevant thoughts exist in the cache, it might bypass the large model entirely to save computational resources. In one embodiment, model selector **620** employs decision trees and heuristics that consider multiple factors including thought relevance scores, computational resource availability, response time requirements, and quality thresholds. It can dynamically adjust its selection criteria based on system load, cache hit rates, and historical performance metrics. Model selector **620** also maintains statistics about the effectiveness of its decisions to continuously refine its selection strategy and may implement different selection policies based on user preferences or application requirements.

(132) A cache manager **630** handles the organization, storage, and retrieval of thoughts in both local and global caches. It implements indexing strategies for quick thought retrieval and manages cache memory efficiently. For example, it might maintain separate indices for different knowledge domains or implement priority-based storage systems where frequently accessed thoughts are kept in faster memory. Cache manager **630** implements eviction policies to optimize cache utilization, considering factors such as but not limited to thought frequency of use, recency, size, and interdependencies with other cached thoughts. It also handles cache coherence between local and global stores, implements versioning and conflict resolution for distributed caches, and maintains metadata about cache performance and utilization patterns. The manager can dynamically adjust its caching strategies based on usage patterns and system resources, potentially implementing different policies for different types of thoughts or knowledge domains.

(133) A thought selector **640** implements algorithms to identify and select the most relevant thoughts from the cache. It uses similarity metrics and relevance scoring to rank cached thoughts based on their applicability to the current prompt. For instance, when processing a prompt about quantum computing applications in cryptography, it might prioritize thoughts that bridge both quantum and cryptographic concepts. Thought selector **640** may employ multiple ranking algorithms that consider various aspects of thought relevance, including semantic similarity, contextual appropriateness, freshness, and historical success rates. It can perform multi-stage selection processes, first identifying broadly relevant thoughts and then refining the selection based on more specific criteria. The selector also considers relationships between thoughts, potentially selecting groups of related thoughts that together provide comprehensive coverage of the prompt's requirements. It maintains performance metrics about selection accuracy and can adapt its selection criteria based on feedback about the effectiveness of selected thoughts in generating successful responses.

(134) A sync controller **650** manages the complex task of synchronizing thoughts between local and global caches. It implements policies for when to upload local thoughts to the global cache and when to download global thoughts to local storage. For example, it might upload locally generated

thoughts about emerging technologies to the global cache while downloading commonly accessed thoughts about fundamental concepts to local storage. Sync controller **650** may employ synchronization strategies that balance network bandwidth usage, storage constraints, and data freshness requirements. It implements conflict resolution mechanisms for handling simultaneous updates, version control for tracking thought evolution, and differential synchronization to minimize data transfer. Sync controller **650** can adapt its sync frequency and policies based on usage patterns, network conditions, and device capabilities. It also maintains detailed synchronization logs and metrics to optimize future sync operations and implements recovery mechanisms for handling failed synchronization attempts. Additionally, sync controller **650** can prioritize synchronization tasks based on thought importance, urgency, and resource availability.

(135) A quality assessor **660** continuously evaluates thought quality and usefulness. It monitors factors such as thought relevance, accuracy, and usage patterns to maintain cache quality. For example, if certain thoughts consistently lead to high-quality responses (as measured by user feedback or other metrics), they might be prioritized for retention and synchronization. Conversely, thoughts that rarely prove useful might be flagged for removal or update. Quality assessor **660** may employ multiple evaluation criteria including syntactic correctness, semantic coherence, factual accuracy, and practical utility. It maintains historical performance metrics for each thought, tracking success rates in different contexts and user satisfaction levels. Quality assessor **660** can detect outdated or inconsistent thoughts, identify redundant thoughts that could be merged, and flag thoughts that may need revision due to changing knowledge or requirements. It implements adaptive quality thresholds that can vary based on thought domain, importance, and usage context. Quality assessor **660** also provides detailed quality reports that can be used to guide cache maintenance operations and thought synthesis decisions, and it can trigger automatic thought improvement processes when quality metrics fall below acceptable thresholds.

Description of Method Aspects

(136) FIG. 7 is a flow diagram illustrating an exemplary method for natural language processing using a dual-model approach with thought generation. In a first step **700**, the system receives a prompt from a user. This prompt can be any form of natural language input, such as a question, command, or statement. For example, a user might input “Explain how quantum entanglement works and its applications in quantum computing.”

(137) In a step **710**, the system processes the prompt through a first large language model. This model is the larger of the two models, containing more parameters and greater processing capability. During this step, the prompt is encoded and processed through the model's architecture to begin the reasoning process. Continuing the example, the large model begins analyzing the quantum entanglement prompt to understand its complexity and required knowledge domains.

(138) In a step **720**, the first large language model converts the prompt into thoughts. These thoughts represent the model's reasoning process and understanding of the prompt's requirements. For the quantum entanglement example, the model might generate thoughts such as: “Quantum entanglement involves pairs of particles maintaining correlated properties regardless of distance” and “In quantum computing, entanglement enables quantum bits to exist in multiple states simultaneously, increasing computational power.”

(139) In a step **730**, the system routes both the original prompt and the generated thoughts to a second large language model that has fewer parameters than the first model. This routing process combines the original prompt and the generated thoughts into a structured input format that the smaller model can efficiently process. Using the example, both the quantum entanglement prompt and the theoretical thoughts about quantum mechanics are packaged together and sent to the smaller model.

(140) In a step **740**, the system generates a response using the second large language model, utilizing both the original prompt and the thoughts generated by the first model. This smaller model, while having fewer parameters, can generate high-quality responses because it has access to

the sophisticated reasoning already performed by the larger model. In the quantum entanglement example, the smaller model can now generate a clear, accurate response by leveraging both the original prompt and the theoretical framework provided by the larger model's thoughts, without needing to independently reason about complex quantum mechanics concepts.

(141) This method enables efficient use of computational resources while maintaining response quality by leveraging the strengths of both models: the sophisticated reasoning capabilities of the larger model and the efficient response generation of the smaller model.

(142) FIG. **8** is a flow diagram illustrating an exemplary method for thought creation, evaluation, and storage within the system. In a first step **800**, the system receives a prompt from a user. This prompt represents any natural language input that requires processing. For example, a user might input “What are the implications of quantum computing on modern cryptography?”

(143) In a step **810**, the prompt analyzer processes the input to determine key concepts and requirements. During this step, the analyzer identifies main topics, subtopics, and relationships between concepts. In our example, the analyzer would identify key concepts such as “quantum computing,” “cryptography,” and their intersection, while also determining the need for forward-looking analysis given the word “implications.”

(144) In a step **820**, the system queries the thought cache to determine if similar thoughts exist. The query process involves searching both local and potentially global caches for thoughts that match the analyzed concepts. For the example, the system might search for existing thoughts about quantum computing's effects on encryption methods, post-quantum cryptography, or quantum-safe algorithms.

(145) In a step **830**, if no similar thoughts exist or existing thoughts aren't sufficiently relevant, the system generates new thoughts using a thought synthesizer. This component may combine fragments of related thoughts or generate entirely new ones. Following the example, if thoughts about quantum computing and modern cryptography exist separately, the synthesizer might combine and adapt them to address their intersection specifically.

(146) In a step **840**, the quality assessor evaluates the newly synthesized thoughts. This evaluation considers factors such as relevance, coherence, and completeness. For instance, it would assess whether the synthesized thoughts about quantum computing's cryptographic implications adequately cover both technical and practical aspects of the topic.

(147) In a step **850**, the system stores the new thoughts in the cache with appropriate metadata and indexing. This step includes tagging the thoughts with relevant keywords, creating appropriate vector embeddings for future similarity searches, and organizing them within the cache's structure. The thoughts about quantum cryptography might be indexed under both quantum computing and cryptography categories, with metadata indicating their relationship to security, encryption, and future technology implications. This method ensures that the system continuously builds and refines its knowledge base while maintaining quality and accessibility of stored thoughts.

(148) FIG. **9** is a flow diagram illustrating an exemplary method for synchronizing thought caches between local devices and a global cloud environment. In a first step **900**, the system initializes a connection between a local device and the cloud environment. This step establishes secure communication channels and verifies authentication credentials. For example, when a user's mobile device connects to the cloud service, it establishes an encrypted connection and validates the device's identity and permissions.

(149) In a step **910**, the system identifies new or modified thoughts in the local cache since the last synchronization event. This involves comparing timestamp metadata and modification flags of local thoughts with the last known sync state. For instance, if a user has generated new thoughts about quantum computing on their device while offline, these would be flagged for potential synchronization.

(150) In a step **920**, the system evaluates the quality and relevance of local thoughts for global storage. This evaluation considers factors such as thought complexity, uniqueness, and potential

value to other users. For example, if a local device has generated highly specialized thoughts about quantum cryptography, the system assesses whether these thoughts would be valuable additions to the global knowledge base.

(151) In a step **930**, the system uploads selected local thoughts to the global cache through the sync controller. This step includes formatting the thoughts for global storage and managing the upload process. Continuing the example, the quantum cryptography thoughts would be packaged with appropriate metadata and transferred to the global cache.

(152) In a step **940**, the system queries the global cache for new relevant thoughts based on the device profile and usage patterns. This involves analyzing the user's interests and recent activities to identify potentially useful thoughts from the global cache. For instance, if the user frequently works with cryptography-related prompts, the system would search for recent additions to the global cache in this domain.

(153) In a step **950**, the system downloads selected global thoughts to the local cache based on relevance and storage capacity. This step optimizes local storage by prioritizing the most relevant thoughts while considering device limitations. For example, the system might download new thoughts about quantum encryption while removing older, less relevant thoughts to maintain optimal cache size.

(154) In a step **960**, the system updates synchronization metadata and timestamps for the next sync cycle. This includes recording which thoughts were synchronized, updating version information, and setting markers for the next synchronization event. This information ensures future sync cycles can efficiently identify new changes and maintain cache consistency. This method enables efficient knowledge sharing across a network of devices while maintaining both local and global thought repositories, effectively creating a distributed learning system that benefits from collective user interactions.

(155) FIG. **10** is a blow diagram illustrating an exemplary system architecture of a thought cache that has both a long-term memory and a short-term memory. In one embodiment, thought cache **370** represents a system for maintaining effectively unlimited context in language models through progressive compression and intelligent caching of thought patterns, enabling shared reasoning across multiple AI instances.

(156) Thought cache **370** implements both a short-term memory **1000** and a long-term memory **1010**. This dual-memory architecture enables the system to maintain both immediate computational context and historical reasoning patterns while managing computational resources efficiently.

(157) The short-term memory **1000** comprises recent thoughts **1020** and an active session cache **1030**. Recent thoughts **1020** maintain complete thought fidelity, storing both the explicit reasoning chains and the internal model states that generated them. This storage preserves not only the textual representation of thoughts but also the computational context and attention patterns that produced them, enabling precise replication of reasoning processes. The active session cache **1030** provides rapid access to these thoughts and their associated states, optimizing performance for ongoing interactions and enabling immediate thought sharing between different AI instances or specialized reasoning modules operating within the same session.

(158) The long-term memory **1010** implements a more sophisticated storage approach through consolidated thoughts **1040** and a persistent cache **1050**. Consolidated thoughts **1040** represent progressively compressed versions of thought patterns, where multiple related thoughts are combined into more compact representations while preserving essential reasoning patterns. This consolidation process employs various compression techniques, including attention-based compression, semantic clustering, and state space reduction. The persistent cache **1050** implements an indexed storage system that enables semantic search and retrieval of these consolidated thoughts, supporting efficient thought sharing across different AI instances and computing sessions.

(159) The system implements bidirectional information flow between these components. Thoughts can move from recent thoughts **1020** to consolidated thoughts **1040** through progressive

compression, while the active session cache **1030** can transfer frequently accessed patterns to the persistent cache **1050** for long-term retention. This bidirectional flow enables dynamic thought sharing between different system components and AI instances, supporting collaborative reasoning across multiple agents.

(160) The architecture supports multiple implementation approaches for thought storage and transfer. Thoughts can be stored as chain-of-thought text, internal model states, attention patterns, or hybrid representations combining multiple formats. The system can dynamically select the most appropriate storage format based on the thought's intended use and the capabilities of the AI instances that may access it.

(161) This architectural design enables the thought cache to serve as a central memory system for multiple AI instances, supporting collaborative reasoning while maintaining computational efficiency. The combination of short-term and long-term memory systems, along with progressive compression and flexible thought representation, allows the system to maintain effectively unlimited context while enabling efficient thought sharing across different AI agents and reasoning modules.

(162) Through this architecture, the system achieves both unbounded context maintenance and efficient cross-instance thought sharing, two key innovations that enable more sophisticated and resource-efficient AI reasoning systems. The design's flexibility in implementation approaches and storage formats helps prevent trivial circumvention while enabling broad application across different types of language models and AI systems.

(163) In one embodiment the system implements a collaborative thought sharing architecture that enables multiple AI agents to access and utilize a common thought cache. This shared cache architecture supports distributed reasoning across different types of language models and specialized reasoning modules while maintaining thought consistency and accessibility. When multiple users or AI agents operate within the system, they can all contribute to and benefit from the accumulated reasoning patterns stored in the shared cache.

(164) The shared thought cache maintains a unified index that enables any authorized user or AI agent to access relevant thoughts regardless of which agent originally generated them. This indexing system tracks not only the content of thoughts but also their originating context, generating agent, and successful usage patterns. For example, when a specialized mathematical reasoning module generates a thought containing a proof strategy, that thought becomes available to general language models handling related mathematical queries, enabling them to leverage expert reasoning patterns without duplicating the computational effort.

(165) Thought transfer between specialized reasoning modules occurs through a standardized thought protocol. This protocol defines how thoughts are packaged, transmitted, and unpacked between different types of AI agents. When transferring thoughts, the system includes not just the reasoning content but also relevant metadata such as the thought's context requirements, assumptions, and compatibility markers. For instance, if a natural language processing agent generates insights about sentence structure, these thoughts can be transferred to a grammar checking module in a format that preserves the structural analysis while adapting it to the specialized module's processing requirements.

(166) The system coordinates collaborative reasoning through a central orchestration mechanism. This orchestrator tracks which agents are actively processing related prompts and manages the flow of thoughts between them. When multiple agents encounter similar reasoning requirements, the orchestrator can initiate thought sharing to prevent redundant computation. For example, if one agent has already performed detailed analysis of a complex concept, other agents can build upon that analysis rather than repeating it.

(167) Cross-instance reasoning is enabled through thought synthesis capabilities. When different model instances approach similar problems from different angles, their thoughts can be combined to create more comprehensive understanding. The system tracks the complementary strengths of

different model instances and can route thoughts to the most appropriate agent for specific types of reasoning tasks. For instance, a general language model might handle initial prompt analysis, while specialized agents process domain-specific aspects, with their combined thoughts contributing to the final response.

(168) The shared cache implements sophisticated access control and version management to maintain thought integrity across multiple agents. Each thought is versioned to track its evolution as different agents interact with and build upon it. The system maintains provenance information that records how thoughts are transformed and combined through multi-agent collaboration, enabling attribution and quality assessment of collaborative reasoning patterns.

(169) Through these mechanisms, the system enables efficient distribution of reasoning tasks across specialized modules while maintaining coherent thought flow. The collaborative architecture allows different AI agents to contribute their specialized capabilities while benefiting from the collective reasoning capacity of the system. This approach significantly reduces computational redundancy while enabling more sophisticated reasoning through the combination of multiple specialized perspectives.

(170) Hardware Architecture

(171) FIG. **11** illustrates an exemplary computing environment on which an embodiment described herein may be implemented, in full or in part. This exemplary computing environment describes computer-related components and processes supporting enabling disclosure of computer-implemented embodiments. Inclusion in this exemplary computing environment of well-known processes and computer components, if any, is not a suggestion or admission that any embodiment is no more than an aggregation of such processes or components. Rather, implementation of an embodiment using processes and components described in this exemplary computing environment will involve programming or configuration of such processes and components resulting in a machine specially programmed or configured for such implementation. The exemplary computing environment described herein is only one example of such an environment and other configurations of the components and processes are possible, including other relationships between and among components, and/or absence of some processes or components described. Further, the exemplary computing environment described herein is not intended to suggest any limitation as to the scope of use or functionality of any embodiment implemented, in whole or in part, on components or processes described herein.

(172) The exemplary computing environment described herein comprises a computing device (further comprising a system bus **11**, one or more processors **20**, a system memory **30**, one or more interfaces **40**, one or more non-volatile data storage devices **50**), external peripherals and accessories **60**, external communication devices **70**, remote computing devices **80**, and cloud-based services **90**.

(173) System bus **11** couples the various system components, coordinating operation of and data transmission between those various system components. System bus **11** represents one or more of any type or combination of types of wired or wireless bus structures including, but not limited to, memory busses or memory controllers, point-to-point connections, switching fabrics, peripheral busses, accelerated graphics ports, and local busses using any of a variety of bus architectures. By way of example, such architectures include, but are not limited to, Industry Standard Architecture (ISA) busses, Micro Channel Architecture (MCA) busses, Enhanced ISA (EISA) busses, Video Electronics Standards Association (VESA) local busses, a Peripheral Component Interconnects (PCI) busses also known as a Mezzanine busses, or any selection of, or combination of, such busses. Depending on the specific physical implementation, one or more of the processors **20**, system memory **30** and other components of the computing device **10** can be physically co-located or integrated into a single physical component, such as on a single chip. In such a case, some or all of system bus **11** can be electrical pathways within a single chip structure.

(174) Computing device may further comprise externally-accessible data input and storage devices

12 such as compact disc read-only memory (CD-ROM) drives, digital versatile discs (DVD), or other optical disc storage for reading and/or writing optical discs **62**; magnetic cassettes, magnetic tape, magnetic disk storage, or other magnetic storage devices; or any other medium which can be used to store the desired content and which can be accessed by the computing device **10**.

Computing device may further comprise externally-accessible data ports or connections **12** such as serial ports, parallel ports, universal serial bus (USB) ports, and infrared ports and/or transmitter/receivers. Computing device may further comprise hardware for wireless communication with external devices such as IEEE 1394 (“Firewire”) interfaces, IEEE 802.11 wireless interfaces, BLUETOOTH® wireless interfaces, and so forth. Such ports and interfaces may be used to connect any number of external peripherals and accessories **60** such as visual displays, monitors, and touch-sensitive screens **61**, USB solid state memory data storage drives (commonly known as “flash drives” or “thumb drives”) **63**, printers **64**, pointers and manipulators such as mice **65**, keyboards **66**, and other devices **67** such as joysticks and gaming pads, touchpads, additional displays and monitors, and external hard drives (whether solid state or disc-based), microphones, speakers, cameras, and optical scanners.

(175) Processors **20** are logic circuitry capable of receiving programming instructions and processing (or executing) those instructions to perform computer operations such as retrieving data, storing data, and performing mathematical calculations. Processors **20** are not limited by the materials from which they are formed or the processing mechanisms employed therein, but are typically comprised of semiconductor materials into which many transistors are formed together into logic gates on a chip (i.e., an integrated circuit or IC). The term processor includes any device capable of receiving and processing instructions including, but not limited to, processors operating on the basis of quantum computing, optical computing, mechanical computing (e.g., using nanotechnology entities to transfer data), and so forth. Depending on configuration, computing device **10** may comprise more than one processor. For example, computing device **10** may comprise one or more central processing units (CPUs) **21**, each of which itself has multiple processors or multiple processing cores, each capable of independently or semi-independently processing programming instructions based on technologies like complex instruction set computer (CISC) or reduced instruction set computer (RISC). Further, computing device **10** may comprise one or more specialized processors such as a graphics processing unit (GPU) **22** configured to accelerate processing of computer graphics and images via a large array of specialized processing cores arranged in parallel. Further computing device **10** may be comprised of one or more specialized processes such as Intelligent Processing Units, field-programmable gate arrays or application-specific integrated circuits for specific tasks or types of tasks. The term processor may further include: neural processing units (NPUs) or neural computing units optimized for machine learning and artificial intelligence workloads using specialized architectures and data paths; tensor processing units (TPUs) designed to efficiently perform matrix multiplication and convolution operations used heavily in neural networks and deep learning applications; application-specific integrated circuits (ASICs) implementing custom logic for domain-specific tasks; application-specific instruction set processors (ASIPs) with instruction sets tailored for particular applications; field-programmable gate arrays (FPGAs) providing reconfigurable logic fabric that can be customized for specific processing tasks;

(176) processors operating on emerging computing paradigms such as quantum computing, optical computing, mechanical computing (e.g., using nanotechnology entities to transfer data), and so forth. Depending on configuration, computing device **10** may comprise one or more of any of the above types of processors in order to efficiently handle a variety of general purpose and specialized computing tasks. The specific processor configuration may be selected based on performance, power, cost, or other design constraints relevant to the intended application of computing device **10**.

(177) System memory **30** is processor-accessible data storage in the form of volatile and/or

nonvolatile memory. System memory **30** may be either or both of two types: non-volatile memory and volatile memory. Non-volatile memory **30a** is not erased when power to the memory is removed, and includes memory types such as read only memory (ROM), electronically-erasable programmable memory (EEPROM), and rewritable solid state memory (commonly known as “flash memory”). Non-volatile memory **30a** is typically used for long-term storage of a basic input/output system (BIOS) **31**, containing the basic instructions, typically loaded during computer startup, for transfer of information between components within computing device, or a unified extensible firmware interface (UEFI), which is a modern replacement for BIOS that supports larger hard drives, faster boot times, more security features, and provides native support for graphics and mouse cursors. Non-volatile memory **30a** may also be used to store firmware comprising a complete operating system **35** and applications **36** for operating computer-controlled devices. The firmware approach is often used for purpose-specific computer-controlled devices such as appliances and Internet-of-Things (IoT) devices where processing power and data storage space is limited. Volatile memory **30b** is erased when power to the memory is removed and is typically used for short-term storage of data for processing. Volatile memory **30b** includes memory types such as random-access memory (RAM), and is normally the primary operating memory into which the operating system **35**, applications **36**, program modules **37**, and application data **38** are loaded for execution by processors **20**. Volatile memory **30b** is generally faster than non-volatile memory **30a** due to its electrical characteristics and is directly accessible to processors **20** for processing of instructions and data storage and retrieval. Volatile memory **30b** may comprise one or more smaller cache memories which operate at a higher clock speed and are typically placed on the same IC as the processors to improve performance.

(178) There are several types of computer memory, each with its own characteristics and use cases. System memory **30** may be configured in one or more of the several types described herein, including high bandwidth memory (HBM) and advanced packaging technologies like chip-on-wafer-on-substrate (CoWoS). Static random access memory (SRAM) provides fast, low-latency memory used for cache memory in processors, but is more expensive and consumes more power compared to dynamic random access memory (DRAM). SRAM retains data as long as power is supplied. DRAM is the main memory in most computer systems and is slower than SRAM but cheaper and more dense. DRAM requires periodic refresh to retain data. NAND flash is a type of non-volatile memory used for storage in solid state drives (SSDs) and mobile devices and provides high density and lower cost per bit compared to DRAM with the trade-off of slower write speeds and limited write endurance. HBM is an emerging memory technology that provides high bandwidth and low power consumption which stacks multiple DRAM dies vertically, connected by through-silicon vias (TSVs). HBM offers much higher bandwidth (up to 1 TB/s) compared to traditional DRAM and may be used in high-performance graphics cards, AI accelerators, and edge computing devices. Advanced packaging and CoWoS are technologies that enable the integration of multiple chips or dies into a single package. CoWoS is a 2.5D packaging technology that interconnects multiple dies side-by-side on a silicon interposer and allows for higher bandwidth, lower latency, and reduced power consumption compared to traditional PCB-based packaging. This technology enables the integration of heterogeneous dies (e.g., CPU, GPU, HBM) in a single package and may be used in high-performance computing, AI accelerators, and edge computing devices.

(179) Interfaces **40** may include, but are not limited to, storage media interfaces **41**, network interfaces **42**, display interfaces **43**, and input/output interfaces **44**. Storage media interface **41** provides the necessary hardware interface for loading data from non-volatile data storage devices **50** into system memory **30** and storage data from system memory **30** to non-volatile data storage device **50**. Network interface **42** provides the necessary hardware interface for computing device **10** to communicate with remote computing devices **80** and cloud-based services **90** via one or more external communication devices **70**. Display interface **43** allows for connection of displays **61**,

monitors, touchscreens, and other visual input/output devices. Display interface **43** may include a graphics card for processing graphics-intensive calculations and for handling demanding display requirements. Typically, a graphics card includes a graphics processing unit (GPU) and video RAM (VRAM) to accelerate display of graphics. In some high-performance computing systems, multiple GPUs may be connected using NVLink bridges, which provide high-bandwidth, low-latency interconnects between GPUs. NVLink bridges enable faster data transfer between GPUs, allowing for more efficient parallel processing and improved performance in applications such as machine learning, scientific simulations, and graphics rendering. One or more input/output (I/O) interfaces **44** provide the necessary support for communications between computing device **10** and any external peripherals and accessories **60**. For wireless communications, the necessary radio-frequency hardware and firmware may be connected to I/O interface **44** or may be integrated into I/O interface **44**. Network interface **42** may support various communication standards and protocols, such as Ethernet and Small Form-Factor Pluggable (SFP). Ethernet is a widely used wired networking technology that enables local area network (LAN) communication. Ethernet interfaces typically use RJ45 connectors and support data rates ranging from 10 Mbps to 100 Gbps, with common speeds being 100 Mbps, 1 Gbps, 10 Gbps, 25 Gbps, 40 Gbps, and 100 Gbps. Ethernet is known for its reliability, low latency, and cost-effectiveness, making it a popular choice for home, office, and data center networks. SFP is a compact, hot-pluggable transceiver used for both telecommunication and data communications applications. SFP interfaces provide a modular and flexible solution for connecting network devices, such as switches and routers, to fiber optic or copper networking cables. SFP transceivers support various data rates, ranging from 100 Mbps to 100 Gbps, and can be easily replaced or upgraded without the need to replace the entire network interface card. This modularity allows for network scalability and adaptability to different network requirements and fiber types, such as single-mode or multi-mode fiber.

(180) Non-volatile data storage devices **50** are typically used for long-term storage of data. Data on non-volatile data storage devices **50** is not erased when power to the non-volatile data storage devices **50** is removed. Non-volatile data storage devices **50** may be implemented using any technology for non-volatile storage of content including, but not limited to, CD-ROM drives, digital versatile discs (DVD), or other optical disc storage; magnetic cassettes, magnetic tape, magnetic disc storage, or other magnetic storage devices; solid state memory technologies such as EEPROM or flash memory; or other memory technology or any other medium which can be used to store data without requiring power to retain the data after it is written. Non-volatile data storage devices **50** may be non-removable from computing device **10** as in the case of internal hard drives, removable from computing device **10** as in the case of external USB hard drives, or a combination thereof, but computing device will typically comprise one or more internal, non-removable hard drives using either magnetic disc or solid state memory technology. Non-volatile data storage devices **50** may be implemented using various technologies, including hard disk drives (HDDs) and solid-state drives (SSDs). HDDs use spinning magnetic platters and read/write heads to store and retrieve data, while SSDs use NAND flash memory. SSDs offer faster read/write speeds, lower latency, and better durability due to the lack of moving parts, while HDDs typically provide higher storage capacities and lower cost per gigabyte. NAND flash memory comes in different types, such as Single-Level Cell (SLC), Multi-Level Cell (MLC), Triple-Level Cell (TLC), and Quad-Level Cell (QLC), each with trade-offs between performance, endurance, and cost. Storage devices connect to the computing device **10** through various interfaces, such as SATA, NVMe, and PCIe. SATA is the traditional interface for HDDs and SATA SSDs, while NVMe (Non-Volatile Memory Express) is a newer, high-performance protocol designed for SSDs connected via PCIe. PCIe SSDs offer the highest performance due to the direct connection to the PCIe bus, bypassing the limitations of the SATA interface. Other storage form factors include M.2 SSDs, which are compact storage devices that connect directly to the motherboard using the M.2 slot, supporting both SATA and NVMe interfaces. Additionally, technologies like Intel Optane memory combine 3D XPoint

technology with NAND flash to provide high-performance storage and caching solutions. Non-volatile data storage devices **50** may be non-removable from computing device **10**, as in the case of internal hard drives, removable from computing device **10**, as in the case of external USB hard drives, or a combination thereof. However, computing devices will typically comprise one or more internal, non-removable hard drives using either magnetic disc or solid-state memory technology. Non-volatile data storage devices **50** may store any type of data including, but not limited to, an operating system **51** for providing low-level and mid-level functionality of computing device **10**, applications **52** for providing high-level functionality of computing device **10**, program modules **53** such as containerized programs or applications, or other modular content or modular programming, application data **54**, and databases **55** such as relational databases, non-relational databases, object oriented databases, NoSQL databases, vector databases, knowledge graph databases, key-value databases, document oriented data stores, and graph databases.

(181) Applications (also known as computer software or software applications) are sets of programming instructions designed to perform specific tasks or provide specific functionality on a computer or other computing devices. Applications are typically written in high-level programming languages such as C, C++, Scala, Erlang, GoLang, Java, Scala, Rust, and Python, which are then either interpreted at runtime or compiled into low-level, binary, processor-executable instructions operable on processors **20**. Applications may be containerized so that they can be run on any computer hardware running any known operating system. Containerization of computer software is a method of packaging and deploying applications along with their operating system dependencies into self-contained, isolated units known as containers. Containers provide a lightweight and consistent runtime environment that allows applications to run reliably across different computing environments, such as development, testing, and production systems facilitated by specifications such as containerd.

(182) The memories and non-volatile data storage devices described herein do not include communication media. Communication media are means of transmission of information such as modulated electromagnetic waves or modulated data signals configured to transmit, not store, information. By way of example, and not limitation, communication media includes wired communications such as sound signals transmitted to a speaker via a speaker wire, and wireless communications such as acoustic waves, radio frequency (RF) transmissions, infrared emissions, and other wireless media.

(183) External communication devices **70** are devices that facilitate communications between computing device and either remote computing devices **80**, or cloud-based services **90**, or both. External communication devices **70** include, but are not limited to, data modems **71** which facilitate data transmission between computing device and the Internet **75** via a common carrier such as a telephone company or internet service provider (ISP), routers **72** which facilitate data transmission between computing device and other devices, and switches **73** which provide direct data communications between devices on a network or optical transmitters (e.g., lasers). Here, modem **71** is shown connecting computing device **10** to both remote computing devices **80** and cloud-based services **90** via the Internet **75**. While modem **71**, router **72**, and switch **73** are shown here as being connected to network interface **42**, many different network configurations using external communication devices **70** are possible. Using external communication devices **70**, networks may be configured as local area networks (LANs) for a single location, building, or campus, wide area networks (WANs) comprising data networks that extend over a larger geographical area, and virtual private networks (VPNs) which can be of any size but connect computers via encrypted communications over public networks such as the Internet **75**. As just one exemplary network configuration, network interface **42** may be connected to switch **73** which is connected to router **72** which is connected to modem **71** which provides access for computing device **10** to the Internet **75**. Further, any combination of wired **77** or wireless **76** communications between and among computing device **10**, external communication devices **70**, remote computing devices **80**, and

cloud-based services **90** may be used. Remote computing devices **80**, for example, may communicate with computing device through a variety of communication channels **74** such as through switch **73** via a wired **77** connection, through router **72** via a wireless connection **76**, or through modem **71** via the Internet **75**. Furthermore, while not shown here, other hardware that is specifically designed for servers or networking functions may be employed. For example, secure socket layer (SSL) acceleration cards can be used to offload SSL encryption computations, and transmission control protocol/internet protocol (TCP/IP) offload hardware and/or packet classifiers on network interfaces **42** may be installed and used at server devices or intermediate networking equipment (e.g., for deep packet inspection).

(184) In a networked environment, certain components of computing device **10** may be fully or partially implemented on remote computing devices **80** or cloud-based services **90**. Data stored in non-volatile data storage device **50** may be received from, shared with, duplicated on, or offloaded to a non-volatile data storage device on one or more remote computing devices **80** or in a cloud computing service **92**. Processing by processors **20** may be received from, shared with, duplicated on, or offloaded to processors of one or more remote computing devices **80** or in a distributed computing service **93**. By way of example, data may reside on a cloud computing service **92**, but may be usable or otherwise accessible for use by computing device **10**. Also, certain processing subtasks may be sent to a microservice **91** for processing with the result being transmitted to computing device **10** for incorporation into a larger processing task. Also, while components and processes of the exemplary computing environment are illustrated herein as discrete units (e.g., OS **51** being stored on non-volatile data storage device **51** and loaded into system memory **35** for use) such processes and components may reside or be processed at various times in different components of computing device **10**, remote computing devices **80**, and/or cloud-based services **90**. Also, certain processing subtasks may be sent to a microservice **91** for processing with the result being transmitted to computing device **10** for incorporation into a larger processing task. Infrastructure as Code (IaaS) tools like Terraform can be used to manage and provision computing resources across multiple cloud providers or hyperscalers. This allows for workload balancing based on factors such as cost, performance, and availability. For example, Terraform can be used to automatically provision and scale resources on AWS spot instances during periods of high demand, such as for surge rendering tasks, to take advantage of lower costs while maintaining the required performance levels. In the context of rendering, tools like Blender can be used for object rendering of specific elements, such as a car, bike, or house. These elements can be approximated and roughed in using techniques like bounding box approximation or low-poly modeling to reduce the computational resources required for initial rendering passes. The rendered elements can then be integrated into the larger scene or environment as needed, with the option to replace the approximated elements with higher-fidelity models as the rendering process progresses.

(185) In an implementation, the disclosed systems and methods may utilize, at least in part, containerization techniques to execute one or more processes and/or steps disclosed herein. Containerization is a lightweight and efficient virtualization technique that allows you to package and run applications and their dependencies in isolated environments called containers. One of the most popular containerization platforms is containerd, which is widely used in software development and deployment. Containerization, particularly with open-source technologies like containerd and container orchestration systems like Kubernetes, is a common approach for deploying and managing applications. Containers are created from images, which are lightweight, standalone, and executable packages that include application code, libraries, dependencies, and runtime. Images are often built from a containerfile or similar, which contains instructions for assembling the image. Containerfiles are configuration files that specify how to build a container image. Systems like Kubernetes natively support containerd as a container runtime. They include commands for installing dependencies, copying files, setting environment variables, and defining runtime configurations. Container images can be stored in repositories, which can be public or

private. Organizations often set up private registries for security and version control using tools such as Harbor, JFrog Artifactory and Bintray, GitLab Container Registry, or other container registries. Containers can communicate with each other and the external world through networking. Container provides a default network namespace, but can be used with custom network plugins. Containers within the same network can communicate using container names or IP addresses.

(186) Remote computing devices **80** are any computing devices not part of computing device **10**. Remote computing devices **80** include, but are not limited to, personal computers, server computers, thin clients, thick clients, personal digital assistants (PDAs), mobile telephones, watches, tablet computers, laptop computers, multiprocessor systems, microprocessor based systems, set-top boxes, programmable consumer electronics, video game machines, game consoles, portable or handheld gaming units, network terminals, desktop personal computers (PCs), minicomputers, mainframe computers, network nodes, virtual reality or augmented reality devices and wearables, and distributed or multi-processing computing environments. While remote computing devices **80** are shown for clarity as being separate from cloud-based services **90**, cloud-based services **90** are implemented on collections of networked remote computing devices **80**.

(187) Cloud-based services **90** are Internet-accessible services implemented on collections of networked remote computing devices **80**. Cloud-based services are typically accessed via application programming interfaces (APIs) which are software interfaces which provide access to computing services within the cloud-based service via API calls, which are pre-defined protocols for requesting a computing service and receiving the results of that computing service. While cloud-based services may comprise any type of computer processing or storage, three common categories of cloud-based services **90** are serverless logic apps, microservices **91**, cloud computing services **92**, and distributed computing services **93**.

(188) Microservices **91** are collections of small, loosely coupled, and independently deployable computing services. Each microservice represents a specific computing functionality and runs as a separate process or container. Microservices promote the decomposition of complex applications into smaller, manageable services that can be developed, deployed, and scaled independently. These services communicate with each other through well-defined application programming interfaces (APIs), typically using lightweight protocols like HTTP, protobufs, gRPC or message queues such as Kafka. Microservices **91** can be combined to perform more complex or distributed processing tasks. In an embodiment, Kubernetes clusters with containerized resources are used for operational packaging of system.

(189) Cloud computing services **92** are delivery of computing resources and services over the Internet **75** from a remote location. Cloud computing services **92** provide additional computer hardware and storage on as-needed or subscription basis. Cloud computing services **92** can provide large amounts of scalable data storage, access to sophisticated software and powerful server-based processing, or entire computing infrastructures and platforms. For example, cloud computing services can provide virtualized computing resources such as virtual machines, storage, and networks, platforms for developing, running, and managing applications without the complexity of infrastructure management, and complete software applications over public or private networks or the Internet on a subscription or alternative licensing basis, or consumption or ad-hoc marketplace basis, or combination thereof.

(190) Federated distributed computing services **93** provide large-scale processing using multiple interconnected computers or nodes to solve computational problems or perform tasks collectively. In federated distributed computing, the processing and storage capabilities of multiple machines are leveraged to work together as a unified system, even when different tiers or tessellations may have limited or even no visibility into the resources and processing layer up or downstream. Federated distributed computing services are designed to address problems that cannot be efficiently solved by a single computer or that require large-scale computational power and require dynamism and workload distribution for economic, security or privacy reasons not well supported by canonical

distributed computing resources; e.g. most commonly cloud-based computing applications, resources or analytics. Federated DCG coordinated variants of these services enable superior decentralization and further enhance parallel processing, fault tolerance, and scalability by distributing tasks across multiple tiers or tessellations while enabling computing process dependency calculation with varying degrees of visibility, assurance and privacy or security based on constituent computing system, network, workload and user or provider needs and preferences as well as practical legal and regulatory concerns to include but not limited to data localization, national data transfer restrictions, privacy and consumer protections, wiretap/telecommunications monitoring requirements, encryption and data routing and intermediate processing restrictions.

(191) Although described above as a physical device, computing device **10** can be a virtual computing device, in which case the functionality of the physical components herein described, such as processors **20**, system memory **30**, network interfaces **40**, and other like components can be provided by computer-executable instructions. Such computer-executable instructions can execute on a single physical computing device, or can be distributed across multiple physical computing devices, including being distributed across multiple physical computing devices in a dynamic manner such that the specific, physical computing devices hosting such computer-executable instructions can dynamically change over time depending upon need and availability. In the situation where computing device **10** is a virtualized device, the underlying physical computing devices hosting such a virtualized computing device can, themselves, comprise physical components analogous to those described above, and operating in a like manner. Furthermore, virtual computing devices can be utilized in multiple layers with one virtual computing device executing within the construct of another virtual computing device. Thus, computing device **10** may be either a physical computing device or a virtualized computing device within which computer-executable instructions can be executed in a manner consistent with their execution by a physical computing device. Similarly, terms referring to physical components of the computing device, as utilized herein, mean either those physical components or virtualizations thereof performing the same or equivalent functions.

(192) The skilled person will be aware of a range of possible modifications of the various aspects described above. Accordingly, the present invention is defined by the claims and their equivalents.

Claims

1. A computer system comprising a hardware memory, wherein the computer system is configured to execute software instructions stored on nontransitory machine-readable storage media that: receive a prompt from a user; process the prompt into a plurality of corresponding thoughts using a first large language model; route both the prompt and the plurality of thoughts through a second large language model that has fewer parameters than the first large language model; associate each corresponding thought in the plurality of corresponding thoughts to a portion of the prompt; cache each associated corresponding thought, wherein a plurality of associated corresponding thoughts may be retrieved from a thought cache when the portion of the prompt they correspond to is present in a future prompt; and generate a response to the prompt by processing the plurality of thoughts and the prompt through the second large language model.
2. The computer system of claim 1, wherein the computer system is further configured to execute software instructions stored on nontransitory machine-readable storage media that: analyze the prompt using a prompt analyzer to determine key concepts and requirements; query the thought cache to determine if similar thoughts exist for the determined key concepts; and synthesize new thoughts when similar thoughts exist but do not fully address the prompt requirements.
3. The computer system of claim 1, wherein the thought cache comprises at least a local cache stored on an edge device and a global cache stored in a cloud environment, wherein the global cache is accessible by a plurality of edge devices.

4. The computer system of claim 3, wherein the global cache is organized into specialized domains, and thoughts are categorized and stored according to their relevant domain.
 5. The computer system of claim 1, wherein caching each associated corresponding thought comprises: evaluating relevance of the thought to the portion of the prompt; assigning metadata tags based on the evaluation; storing the thought with vector embeddings for similarity searching; and indexing the thought for retrieval.
 6. The computer system of claim 1, wherein caching each associated corresponding thought comprises: storing each associated corresponding thought in a short-term memory as explicit reasoning text; progressively compressing a plurality of older associated corresponding thoughts into consolidated representations; and storing a plurality of compressed older associated corresponding thoughts in a long-term memory.
 7. The computer system of claim 1, wherein the computer system is further configured to execute software instructions stored on nontransitory machine-readable storage media that: maintain a shared thought cache accessible by multiple AI agents; enable thought transfer between specialized reasoning modules; and coordinate collaborative reasoning across multiple model instances.
 8. A method for encrypted data compression with a hardware management layer, comprising the steps of: receiving a prompt from a user; processing the prompt into a plurality of corresponding thoughts using a first large language model; routing both the prompt and the plurality of thoughts through a second large language model that has fewer parameters than the first large language model; associating each corresponding thought in the plurality of corresponding thoughts to a portion of the prompt; caching each associated corresponding thought, wherein a plurality of associated corresponding thoughts may be retrieved from a thought cache when the portion of the prompt they correspond to is present in a future prompt; and generating a response to the prompt by processing the plurality of thoughts and the prompt through the second large language model.
 9. The method of claim 8, further comprising the steps of: analyzing the prompt using a prompt analyzer to determine key concepts and requirements; querying the thought cache to determine if similar thoughts exist for the determined key concepts; and synthesizing new thoughts when similar thoughts exist but do not fully address the prompt requirements.
 10. The method of claim 8, wherein the thought cache comprises at least a local cache stored on an edge device and a global cache stored in a cloud environment, wherein the global cache is accessible by a plurality of edge devices.
 11. The method of claim 10, wherein the global cache is organized into specialized domains, and thoughts are categorized and stored according to their relevant domain.
 12. The method of claim 8, wherein caching each associated corresponding thought comprises: evaluating relevance of the thought to the portion of the prompt; assigning metadata tags based on the evaluation; storing the thought with vector embeddings for similarity searching; and indexing the thought for retrieval.
 13. The method of claim 8, wherein caching each associated corresponding thought comprises: storing each associated corresponding thought in a short-term memory as explicit reasoning text; progressively compressing a plurality of older associated corresponding thoughts into consolidated representations; and storing a plurality of compressed older associated corresponding thoughts in a long-term memory.
 14. The method of claim 8, further comprising the steps of: maintaining a shared thought cache accessible by multiple AI agents; enabling thought transfer between specialized reasoning modules; and coordinating collaborative reasoning across multiple model instances.
-