AI ENGINEER CAREER TRACK – 2025 EDITION

" Building Intelligent Systems for the Future"

Market Demand Note

AI Engineers are at the forefront of the **4th Industrial Revolution**, driving innovation in **Generative AI, Autonomous Systems, Natural Language Processing, and Computer Vision**.
Global demand for AI engineers is projected to grow by **40% annually** over the next five years.

Duration: 4–5 Months | **Mode**: Online/Offline

📘 AI Engineer Career Track — 2025 Edition

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Module 1: Introduction to AI Engineering (10 Hours)

🎯 Learning Objectives:

- Understand the evolving role of AI Engineers in the age of Generative AI and LLMs
- Master AI system architecture and design patterns for production environments
- Develop ethical AI mindset with responsible AI practices and bias mitigation
- Learn the distinction between AI Engineers, ML Engineers, and Data Scientists in 2025

📋 Detailed Topics Covered:

AI Engineer Role in 2025 (3 Hours)

- Modern AI Engineer Responsibilities:
    - AI System Architecture: Designing end-to-end AI systems with multiple models and components
    - LLM Integration: Incorporating large language models into production applications
    - Multimodal AI Development: Building systems that handle text, images, audio, and video
    - AI Product Development: From POC to production-ready AI applications
    - Cross-functional Leadership: Working with product managers, UX designers, and business stakeholders

- Industry Salary Trends: AI Engineers earn ₹15-50 LPA in product companies (higher than ML Engineers)
- Career Progression: Junior AI Engineer → Senior AI Engineer → AI Architect → VP of AI
- Emerging Specializations: Prompt Engineers, AI Safety Engineers, Multimodal AI Specialists

AI vs ML vs Data Science (2 Hours)

- AI Engineering Focus: Building intelligent systems that can reason, learn, and interact
- ML Engineering Focus: Optimizing model performance, deployment, and monitoring
- Data Science Focus: Extracting insights and patterns from data for business decisions
- Convergence in 2025: How roles are blending with GenAI and LLM technologies
- Real-world Examples:
    - AI Engineer: Building ChatGPT-like conversational AI for customer service
    - ML Engineer: Optimizing recommendation algorithm performance
    - Data Scientist: Analyzing customer churn patterns for business strategy

Types of AI and Modern Applications (2.5 Hours)

- Current AI Categories:
    - Narrow AI (ANI): Specialized systems like recommendation engines, image classifiers
    - Artificial General Intelligence (AGI): Human-level AI (theoretical, research stage)
    - Superintelligence: Beyond human capability (speculative)
- 2025 AI Application Landscape:
    - Generative AI: Content creation, code generation, creative applications
    - Conversational AI: Advanced chatbots, voice assistants, virtual companions
    - Autonomous Systems: Self-driving cars, robotic process automation

    - Multimodal AI: Systems that understand and generate text, images, audio, video
    - Agentic AI: Autonomous agents that can plan, reason, and take actions

AI System Architecture & Lifecycle (2.5 Hours)

- Modern AI System Components:
    - Data Layer: Real-time data ingestion, preprocessing, feature stores
    - Model Layer: Multiple specialized models, ensemble systems, model orchestration
    - Intelligence Layer: Reasoning engines, planning systems, decision frameworks
    - Interface Layer: APIs, user interfaces, integration endpoints
- AI Development Lifecycle:
    - Problem Definition: Business requirements, success metrics, constraint identification
    - Data Strategy: Data collection, quality assessment, privacy considerations
    - Model Development: Algorithm selection, training, validation, optimization
    - System Integration: Component assembly, testing, performance optimization
    - Deployment: Production deployment, monitoring, continuous improvement
- Production Considerations: Scalability, latency, cost optimization, reliability

🛠️ Practical Exercises:

1. AI Use Case Mapping: Analyze and design AI solutions for healthcare (diagnosis assistant), finance (fraud detection + advisory), and retail (personalized shopping assistant)
2. AI System Design: Create architecture diagram for a complete AI-powered customer service system with chat, voice, and multimodal capabilities
3. Ethics Assessment: Evaluate an existing AI system for bias, fairness, and potential negative impacts with mitigation strategies

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Module 2: Python & Data Fundamentals (12 Hours)

🎯 Learning Objectives:

- Master Python programming with focus on AI application development
- Build expertise in handling diverse data types for AI systems (text, images, audio)
- Develop skills in API integration and real-time data processing
- Create robust data pipelines for AI model training and inference

📋 Detailed Topics Covered:

Advanced Python for AI Development (4 Hours)

- Production Python Practices:
    - Code Architecture: Modular design, dependency injection, configuration management
    - Object-Oriented Design: Abstract classes, inheritance patterns for AI components
    - Error Handling: Custom exceptions, logging strategies, graceful degradation
    - Performance Optimization: Async programming, concurrent processing, memory management
- AI-Specific Libraries:
    - Core Libraries: NumPy for numerical computing, SciPy for scientific computing
    - Data Manipulation: Pandas for structured data, Polars for high-performance processing
    - Utility Libraries: pathlib for file handling, json/pickle for serialization
- Development Environment:
    - Virtual Environments: Poetry, conda, pip-tools for dependency management
    - Code Quality: Black for formatting, pylint for linting, mypy for type checking
    - Testing: pytest for unit testing, hypothesis for property-based testing

Data Analysis & Visualization (4 Hours)

- Advanced Pandas Techniques:
    - Data Structures: MultiIndex DataFrames, categorical data, sparse arrays
    - Data Cleaning: Missing value strategies, outlier detection, data validation
    - Text Processing: String manipulation, regex patterns, text normalization
    - Time Series: DatetimeIndex, resampling, rolling windows, timezone handling
- NumPy for AI:
    - Array Operations: Broadcasting, advanced indexing, memory layout optimization
    - Mathematical Functions: Linear algebra, statistical functions, random number generation
    - Integration: Seamless conversion between pandas and NumPy for performance
- Visualization for AI:
    - Matplotlib: Custom plots, animations, publication-quality figures
    - Seaborn: Statistical plots, multi-dimensional data visualization
    - Plotly: Interactive dashboards, 3D visualizations, real-time updating plots

Working with Unstructured Data (4 Hours)

- JSON and API Integration:
    - JSON Processing: Complex nested structures, schema validation, streaming JSON
    - REST API Consumption: Authentication, rate limiting, error handling, async requests
    - API Development: FastAPI basics, request validation, response serialization
- Text Data Processing:
    - File Formats: CSV, Excel, Parquet, JSON Lines for different data scenarios
    - Text Encoding: Unicode handling, character set detection, normalization
    - Web Scraping: BeautifulSoup, Scrapy, handling dynamic content with Selenium

- Multimedia Data:
    - Image Processing: PIL/Pillow for basic operations, format conversions
    - Audio Processing: librosa for audio analysis, wave file manipulation
    - Video Processing: OpenCV basics, frame extraction, metadata handling

🛠️ Practical Exercises:

1. Multi-source Data Pipeline: Build system that collects data from APIs, databases, files, and web scraping, then processes and stores it efficiently
2. Real-time Data Processor: Create async Python application that processes streaming data from multiple sources with error handling and monitoring
3. AI Data Preprocessor: Develop comprehensive preprocessing pipeline that handles text, images, and structured data for AI model training
4. Interactive Data Explorer: Build Plotly dashboard for exploring complex datasets with filtering, drill-down, and export capabilities

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Module 3: Mathematics & AI Foundations (13 Hours)

🎯 Learning Objectives:

- Build solid mathematical foundation for understanding modern AI algorithms
- Master optimization techniques used in deep learning and neural networks
- Develop intuition for probability and statistics in AI applications
- Understand graph theory concepts essential for modern AI architectures

📋 Detailed Topics Covered:

Linear Algebra for AI Systems (4 Hours)

- Vector Operations and Spaces:
    - Vector Fundamentals: Geometric interpretation, basis vectors, linear independence
    - Vector Operations: Dot product, cross product, norms (L1, L2, infinity)
    - Applications in AI: Similarity measures, distance metrics, feature representations
- Matrix Operations and Decomposition:
    - Matrix Arithmetic: Addition, multiplication, transpose, inverse operations

        - Eigenvalues/Eigenvectors: PCA mathematical foundation, dimensionality reduction
        - Matrix Decomposition: SVD, QR, LU for data compression and analysis
        - Tensors: Multi-dimensional arrays, tensor operations in deep learning
    - Practical AI Applications:
        - Word Embeddings: Vector representations of words, semantic similarity
        - Recommendation Systems: Matrix factorization, collaborative filtering
        - Neural Network Math: Weight matrices, gradient computation, backpropagation

Probability & Statistics for AI (4 Hours)

- Probability Fundamentals:
    - Basic Probability: Events, sample spaces, conditional probability
    - Bayes' Theorem: Prior/posterior probability, Bayesian inference in AI
    - Probability Distributions: Normal, binomial, Poisson, exponential distributions
- Statistical Inference for AI:
    - Sampling Theory: Central limit theorem, confidence intervals, hypothesis testing
    - Bayesian Statistics: Bayesian networks, MCMC methods, probabilistic programming
    - Information Theory: Entropy, mutual information, KL divergence
- AI-Specific Applications:
    - Uncertainty Quantification: Model confidence, prediction intervals
    - A/B Testing: Experimental design for AI system evaluation
    - Anomaly Detection: Statistical methods for outlier identification

Calculus & Optimization (3 Hours)

- Differential Calculus:
    - Derivatives: Chain rule, partial derivatives, gradients
    - Multivariate Calculus: Jacobians, Hessians, Taylor expansions

        - Applications: Understanding how neural networks learn, optimization landscapes
- Optimization Algorithms:
    - Gradient Descent: Vanilla, momentum, adaptive learning rates (AdaGrad, Adam)
    - Constrained Optimization: Lagrange multipliers, KKT conditions
    - Convex Optimization: Convex functions, global vs local optima
    - Evolutionary Algorithms: Genetic algorithms, particle swarm optimization
- Modern AI Optimization:
    - Learning Rate Scheduling: Cosine annealing, warm restarts, cyclic learning rates
    - Second-order Methods: Newton's method, L-BFGS for large-scale optimization
    - Hyperparameter Optimization: Bayesian optimization, population-based training

Graph Theory for AI (2 Hours)

- Graph Fundamentals:
    - Graph Representation: Adjacency matrices, adjacency lists, edge lists
    - Graph Types: Directed/undirected, weighted/unweighted, bipartite graphs
    - Graph Properties: Connectivity, paths, cycles, centrality measures
- AI Search Algorithms:
    - Uninformed Search: Breadth-first search, depth-first search, uniform cost search
    - Informed Search: A* algorithm, heuristic functions, admissibility
    - Advanced Search: Monte Carlo Tree Search, minimax with alpha-beta pruning
- Modern Applications:
    - Knowledge Graphs: Entity relationships, semantic networks, graph databases
    - Graph Neural Networks: Message passing, graph convolutions, node embeddings

- Social Network Analysis: Community detection, influence propagation, link prediction

🛠️ Practical Exercises:

1. Linear Algebra Implementation: Build PCA algorithm from scratch using only NumPy, compare with scikit-learn implementation
2. Optimization Visualization: Implement and visualize different optimization algorithms on various loss landscapes
3. *A Search Implementation**: Build complete A* pathfinding algorithm with custom heuristics and visualize search process
4. Probability Simulation: Create Monte Carlo simulation for complex probability problems relevant to AI applications
5. Graph Analysis Project: Analyze social network data using graph theory concepts and implement community detection algorithms

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Module 4: Machine Learning for AI Engineers (18 Hours)

🎯 Learning Objectives:

- Master machine learning algorithms as building blocks for AI systems
- Develop expertise in feature engineering and model evaluation for AI applications
- Build ensemble systems and advanced ML techniques for production AI
- Understand when to use different ML approaches within larger AI architectures

📋 Detailed Topics Covered:

Feature Engineering for AI Systems (4.5 Hours)

- Advanced Feature Creation:
    - Domain-Specific Features: Time-based features, geospatial features, text features
    - Automated Feature Engineering: Polynomial features, interaction terms, feature crosses
    - Feature Selection: Filter methods, wrapper methods, embedded methods, recursive feature elimination

        - Dimensionality Reduction: PCA, t-SNE, UMAP, autoencoders for feature learning
- Text Feature Engineering:
    - Traditional Methods: Bag-of-words, TF-IDF, n-grams, character-level features
    - Modern Embeddings: Word2Vec, GloVe, FastText, contextual embeddings
    - Feature Extraction: Named entities, part-of-speech tags, sentiment scores
- Image Feature Engineering:
    - Traditional CV Features: HOG, SIFT, color histograms, texture features
    - Deep Learning Features: Pre-trained CNN features, feature pyramid networks
    - Data Augmentation: Geometric transformations, color adjustments, advanced techniques

Supervised Learning Algorithms (6 Hours)

- Linear Models for AI:
    - Linear Regression: Multiple regression, polynomial features, regularization (Ridge, Lasso, Elastic Net)
    - Logistic Regression: Binary/multiclass classification, feature interpretation, regularization
    - Applications in AI: Feature importance, baseline models, interpretable components
- Tree-Based Models:
    - Decision Trees: Information gain, Gini impurity, pruning strategies, interpretability
    - Random Forest: Bootstrap aggregating, out-of-bag error, feature importance, parallelization
    - Gradient Boosting: XGBoost, LightGBM, CatBoost - advanced hyperparameter tuning
    - AI System Integration: Ensemble voting, stacking, model chains
- Advanced Algorithms:

    - Support Vector Machines: Kernel trick, hyperparameter tuning, high-dimensional data
    - k-Nearest Neighbors: Distance metrics, curse of dimensionality, locality-sensitive hashing
    - Naive Bayes: Assumptions, text classification, probabilistic reasoning

Unsupervised Learning & Pattern Discovery (4 Hours)

- Clustering Algorithms:
    - K-Means: Algorithm details, initialization strategies, elbow method, silhouette analysis
    - Hierarchical Clustering: Agglomerative/divisive methods, dendrograms, linkage criteria
    - Density-Based Clustering: DBSCAN, handling noise and outliers, parameter tuning
    - Advanced Methods: Gaussian mixture models, spectral clustering, mean shift
- Dimensionality Reduction:
    - Principal Component Analysis: Mathematical derivation, explained variance, component interpretation
    - t-SNE: Non-linear visualization, perplexity parameter, limitations and best practices
    - UMAP: Uniform manifold approximation, preserving global structure, parameter selection
- Association Rule Mining:
    - Market Basket Analysis: Support, confidence, lift metrics, Apriori algorithm
    - Applications in AI: Recommendation systems, feature interaction discovery

Model Evaluation & Advanced Techniques (3.5 Hours)

- Comprehensive Model Evaluation:
    - Classification Metrics: Accuracy, precision, recall, F1-score, ROC-AUC, PR-AUC
    - Regression Metrics: MSE, RMSE, MAE, R^2, MAPE, quantile losses

    - Cross-Validation: K-fold, stratified, time series splits, nested CV
    - Statistical Significance: Paired t-tests, McNemar's test, confidence intervals
- Handling Real-World Challenges:
    - Imbalanced Data: SMOTE, ADASYN, cost-sensitive learning, threshold optimization
    - Concept Drift: Detection methods, adaptive models, online learning strategies
    - Multi-label Classification: Binary relevance, classifier chains, label powerset
- Advanced Model Selection:
    - Hyperparameter Optimization: Grid search, random search, Bayesian optimization
    - Automated Machine Learning: Auto-sklearn, TPOT, H2O AutoML integration
    - Model Interpretability: SHAP values, LIME, permutation importance, partial dependence plots

🛠️ Practical Exercises:

1. Spam Detection System: Build complete email classification system with feature engineering, model comparison, and interpretability analysis
2. Customer Segmentation Project: Implement unsupervised learning pipeline for customer clustering with business insights and recommendations
3. Ensemble Model Competition: Create advanced ensemble system combining multiple algorithms with automated hyperparameter tuning
4. Imbalanced Dataset Challenge: Handle severely imbalanced fraud detection dataset using multiple techniques and compare results
5. Model Interpretability Dashboard: Build interactive dashboard showing model decisions, feature importance, and prediction explanations

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Module 5: Deep Learning & Neural Architectures (22 Hours)

🎯 Learning Objectives:

- Master modern neural network architectures for diverse AI applications

- Develop expertise in TensorFlow and PyTorch for production AI systems
- Implement attention mechanisms and transformer architectures
- Build and fine-tune state-of-the-art models for real-world problems

📋 Detailed Topics Covered:

Neural Network Fundamentals (5 Hours)

- Mathematical Foundations (2 Hours):
    - Perceptron Model: Linear separability, activation functions, learning algorithm
    - Multilayer Perceptrons: Universal approximation theorem, hidden layer roles
    - Backpropagation: Mathematical derivation, chain rule application, computational graphs
    - Optimization: Loss functions, gradient computation, parameter updates
- Network Architecture Design (1.5 Hours):
    - Activation Functions: ReLU variants, GELU, Swish, choosing appropriate activations
    - Weight Initialization: Xavier/Glorot, He initialization, impact on training dynamics
    - Regularization Techniques: Dropout, batch normalization, layer normalization, weight decay
    - Architecture Patterns: Skip connections, residual blocks, dense connections
- Training Strategies (1.5 Hours):
    - Batch Processing: Mini-batch gradient descent, batch size effects, memory considerations
    - Learning Rate Management: Scheduling, adaptive methods, learning rate finding
    - Training Monitoring: Loss curves, validation strategies, early stopping
    - Advanced Techniques: Gradient clipping, label smoothing, mixup augmentation

Deep Learning Frameworks (6 Hours)

- TensorFlow & Keras Mastery (3 Hours):
    - Keras API Levels: Sequential, Functional, Subclassing for different use cases
    - Custom Components: Custom layers, losses, metrics, training loops
    - Data Pipeline: tf.data for efficient data loading, preprocessing, and augmentation
    - Model Deployment: SavedModel format, TensorFlow Serving, TensorFlow Lite for mobile
    - Advanced Features: Mixed precision training, multi-GPU strategies, TPU integration
- PyTorch Deep Dive (3 Hours):
    - Tensor Operations: Autograd system, computational graphs, memory management
    - Module System: nn.Module, parameter management, state dictionaries
    - Data Loading: DataLoader, Dataset classes, custom samplers, data augmentation
    - Training Framework: Manual training loops, PyTorch Lightning for structure
    - Production Deployment: TorchScript, ONNX export, model optimization

Convolutional Neural Networks (5 Hours)

- CNN Architecture (2.5 Hours):
    - Convolution Operation: Filters, feature maps, stride, padding, dilation
    - Pooling Layers: Max pooling, average pooling, global pooling, learnable pooling
    - Classic Architectures: LeNet, AlexNet, VGG, ResNet, DenseNet evolution
    - Modern Architectures: EfficientNet, RegNet, ConvNeXt, architecture search
- Advanced CNN Techniques (2.5 Hours):
    - Transfer Learning: Feature extraction vs fine-tuning, layer freezing strategies
    - Data Augmentation: Geometric transformations, color adjustments, CutOut, MixUp, CutMix

    - Attention in CNNs: Spatial attention, channel attention, self-attention mechanisms
    - Object Detection: YOLO architecture, anchor-based vs anchor-free methods

Recurrent Neural Networks & Sequences (3 Hours)

- RNN Fundamentals (1 Hour):
    - Vanilla RNNs: Sequence processing, hidden states, vanishing gradient problem
    - LSTM Architecture: Gates, cell states, forget/input/output gates detailed explanation
    - GRU Networks: Simplified gating, when to use vs LSTM, performance comparisons
- Advanced Sequence Modeling (2 Hours):
    - Bidirectional RNNs: Processing sequences in both directions, concatenation strategies
    - Sequence-to-Sequence: Encoder-decoder architecture, attention mechanisms
    - Time Series Applications: Multi-step forecasting, multivariate time series
    - Text Generation: Character-level vs word-level, beam search, nucleus sampling

Attention Mechanisms & Transformers (3 Hours)

- Attention Fundamentals (1.5 Hours):
    - Attention Concept: Query, key, value paradigm, attention weights computation
    - Self-Attention: Intra-sequence relationships, positional encoding
    - Multi-Head Attention: Parallel attention heads, concatenation and projection
    - Scaled Dot-Product Attention: Mathematical formulation, computational efficiency
- Transformer Architecture (1.5 Hours):
    - Encoder-Decoder Structure: Layer normalization, residual connections, feed-forward networks

    - Positional Encoding: Sinusoidal encoding, learned positional embeddings
    - Pre-trained Transformers: BERT (encoder-only), GPT (decoder-only), T5 (encoder-decoder)
    - Fine-tuning Strategies: Task-specific heads, adapter methods, prompt tuning

🛠️ Practical Exercises:

1. Custom CNN Architecture: Design and implement novel CNN architecture for specific image classification task with detailed performance analysis
2. LSTM Time Series Predictor: Build comprehensive time series forecasting system with multiple input features and multi-step predictions
3. Transformer Fine-tuning: Fine-tune pre-trained transformer model for domain-specific text classification with evaluation on multiple metrics
4. Multi-modal Neural Network: Create network that processes both text and image inputs for unified understanding task
5. Neural Architecture Search: Implement simplified NAS to automatically discover optimal architecture for given problem

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Module 6: Generative AI & Large Language Models (20 Hours)

🎯 Learning Objectives:

- Master the latest generative AI technologies and LLM architectures
- Build production-ready applications using open-source language models
- Develop expertise in prompt engineering and model fine-tuning techniques
- Create intelligent agents and RAG systems for real-world applications

📋 Detailed Topics Covered:

Generative Models Fundamentals (5 Hours)

- Generative Adversarial Networks (2.5 Hours):
    - GAN Architecture: Generator and discriminator networks, adversarial training
    - Training Challenges: Mode collapse, vanishing gradients, training instability

        - Advanced GAN Variants: DCGAN, StyleGAN, CycleGAN, conditional GANs
        - Applications: Image synthesis, style transfer, data augmentation
        - Evaluation Metrics: Inception Score, FID, precision and recall for GANs
    - Variational Autoencoders (1.5 Hours):
        - VAE Architecture: Encoder, decoder, latent space, reparameterization trick
        - Loss Function: Reconstruction loss, KL divergence, beta-VAE variants
        - Applications: Anomaly detection, data compression, generative modeling
    - Diffusion Models (1 Hour):
        - Stable Diffusion: Text-to-image generation, ControlNet for guided generation
        - Denoising Process: Forward and reverse diffusion, sampling techniques
        - Applications: Image generation, inpainting, super-resolution

Large Language Models Architecture (6 Hours)

- Transformer Language Models (3 Hours):
    - GPT Architecture: Decoder-only transformers, causal attention masking
    - BERT Architecture: Encoder-only transformers, bidirectional attention
    - T5 Architecture: Text-to-text unified framework, encoder-decoder structure
    - Modern Variants: RoBERTa, ELECTRA, DeBERTa architectural improvements
- Scaling Laws and Training (2 Hours):
    - Model Scaling: Parameters, compute, data relationships (Chinchilla scaling)
    - Training Infrastructure: Distributed training, gradient accumulation, mixed precision
    - Pre-training Objectives: Masked language modeling, next token prediction, span corruption
    - Tokenization: Byte-pair encoding, WordPiece, SentencePiece strategies

- Open Source LLM Ecosystem (1 Hour):
    - Popular Models: Llama 2, Mistral, CodeLlama, Phi-2, Gemma
    - Model Formats: GGUF, GGML, safetensors, quantized models
    - Local Deployment: Ollama, LM Studio, text-generation-webui
    - Hardware Requirements: CPU vs GPU inference, memory considerations

LLM Fine-tuning and Customization (4.5 Hours)

- Fine-tuning Strategies (2.5 Hours):
    - Full Fine-tuning: Complete parameter updates, computational requirements
    - Parameter-Efficient Fine-tuning: LoRA, AdaLoRA, QLoRA implementations
    - Instruction Tuning: Creating instruction-following models, dataset formatting
    - RLHF (Reinforcement Learning from Human Feedback): Alignment techniques
- Dataset Preparation (1 Hour):
    - Data Collection: Web scraping, API data, synthetic data generation
    - Data Cleaning: Deduplication, quality filtering, bias detection
    - Format Conversion: Chat format, instruction-response pairs, system prompts
    - Evaluation Datasets: Creating test sets, holdout strategies
- Training Implementation (1 Hour):
    - Hugging Face Transformers: Trainer API, custom training loops
    - PEFT Library: LoRA implementation, adapter management
    - Hardware Optimization: Gradient checkpointing, DeepSpeed integration
    - Monitoring: Loss curves, evaluation metrics, early stopping

Prompt Engineering & LLM Applications (4.5 Hours)

- Advanced Prompt Engineering (2 Hours):
    - Zero-shot Prompting: Effective instruction design, output formatting

    - Few-shot Learning: Example selection, context window management
    - Chain-of-Thought: Step-by-step reasoning, complex problem solving
    - Tree of Thoughts: Multi-path reasoning, decision tree exploration
    - Constitutional AI: Self-correction, principle-based responses
- LLM Integration Frameworks (1.5 Hours):
    - LangChain: Chains, agents, memory systems, tool integration
    - LlamaIndex: Document indexing, retrieval systems, query engines
    - Haystack: Pipeline architecture, retrieval-augmented generation
    - Custom Integration: Direct API calls, streaming responses, error handling
- RAG (Retrieval-Augmented Generation) (1 Hour):
    - Vector Databases: ChromaDB, FAISS, Qdrant for embeddings storage
    - Embedding Models: Sentence transformers, domain-specific embeddings
    - Retrieval Strategies: Semantic search, hybrid search, re-ranking
    - Context Management: Chunk optimization, context window utilization

🛠️ Practical Exercises:

1. Custom LLM Fine-tuning: Fine-tune open-source LLM on domain-specific dataset using LoRA with comprehensive evaluation
2. RAG System Development: Build complete RAG system with document ingestion, semantic search, and response generation
3. Multi-Agent LLM System: Create collaborative AI agents that can communicate and solve complex tasks together
4. GAN Implementation: Build and train GAN for specific image generation task with quality assessment
5. Prompt Engineering Competition: Develop advanced prompting strategies for complex reasoning tasks with performance benchmarking

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Module 7: NLP & Computer Vision Applications (15 Hours)

🎯 Learning Objectives:

- Build production-ready NLP systems using modern transformer architectures

- Develop computer vision applications with state-of-the-art deep learning models
- Create multimodal AI systems that combine text and vision capabilities
- Deploy NLP and CV models with optimal performance and scalability

📋 Detailed Topics Covered:

Advanced Natural Language Processing (8 Hours)

- Modern NLP Pipelines (3 Hours):
    - Text Preprocessing 2025: Modern tokenization, Unicode normalization, language detection
    - Advanced Tokenization: Subword tokenization, handling multilingual text, custom vocabularies
    - Named Entity Recognition: spaCy, Hugging Face NER models, custom entity extraction
    - Dependency Parsing: Syntactic analysis, grammar trees, linguistic feature extraction
    - Sentiment Analysis: Fine-grained emotion detection, aspect-based sentiment analysis
- Transformer-based NLP (3 Hours):
    - BERT Applications: Text classification, token classification, question answering
    - GPT Applications: Text generation, completion, creative writing, code generation
    - T5 Framework: Text-to-text tasks, summarization, translation, question generation
    - Multilingual Models: mBERT, XLM-R, cross-lingual transfer learning
    - Domain Adaptation: Fine-tuning for specific domains (legal, medical, financial)
- Advanced NLP Applications (2 Hours):
    - Document Understanding: Layout analysis, table extraction, form processing
    - Conversational AI: Intent recognition, slot filling, dialogue state tracking

    - Information Extraction: Relation extraction, knowledge graph construction
    - Text Summarization: Extractive vs abstractive, multi-document summarization
    - Machine Translation: Sequence-to-sequence models, attention visualization

Computer Vision Applications (7 Hours)

- Image Processing & Feature Extraction (2 Hours):
    - OpenCV Advanced: Image filtering, morphological operations, contour detection
    - Traditional CV Features: SIFT, SURF, ORB for keypoint detection and matching
    - Image Enhancement: Histogram equalization, noise reduction, super-resolution
    - Geometric Transformations: Perspective correction, image alignment, panorama stitching
- Deep Learning for Computer Vision (3 Hours):
    - Image Classification: Fine-tuning pre-trained models, data augmentation strategies
    - Object Detection: YOLO v8, Detectron2, real-time performance optimization
    - Image Segmentation: Semantic segmentation with U-Net, instance segmentation with Mask R-CNN
    - Face Recognition: FaceNet, ArcFace, anti-spoofing techniques, privacy considerations
- Advanced CV Applications (2 Hours):
    - Optical Character Recognition: Tesseract, TrOCR, document digitization
    - Video Analysis: Frame-by-frame processing, temporal consistency, action recognition
    - Generative CV: Style transfer, image inpainting, super-resolution with GANs

    - 3D Computer Vision: Depth estimation, 3D reconstruction, point cloud processing

🛠️ Practical Exercises:

1. Multilingual Text Classifier: Build classifier that works across multiple languages with cross-lingual evaluation
2. Real-time Object Detection: Implement optimized object detection system for video streams with performance benchmarking
3. Document AI System: Create system that can extract structured information from various document types
4. Multimodal Search Engine: Build search system that can find relevant content using both text and image queries
5. Vision-Language Model: Develop model that can generate captions for images and answer questions about visual content

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Module 8: AI System Design & MLOps (15 Hours)

🎯 Learning Objectives:

- Design scalable AI system architectures for production environments
- Master MLOps practices specifically for AI applications with LLMs and multimodal models
- Implement monitoring and maintenance strategies for AI systems
- Build CI/CD pipelines optimized for AI model deployment and updates

📋 Detailed Topics Covered:

AI System Architecture & Design (5 Hours)

- Scalable AI System Design (2.5 Hours):
    - Microservices Architecture: Service decomposition, API gateways, inter-service communication
    - Event-Driven Architecture: Message queues, pub-sub patterns, async processing
    - Data Architecture: Real-time vs batch processing, data lakes vs warehouses, streaming pipelines

        - Model Orchestration: Model chaining, ensemble coordination, fallback strategies
        - Performance Considerations: Latency optimization, throughput scaling, resource allocation
- AI-Specific Infrastructure (2.5 Hours):
    - GPU Management: Resource allocation, memory optimization, multi-tenancy
    - Model Serving: Batch inference, real-time serving, streaming inference
    - Caching Strategies: Model caching, result caching, intelligent cache invalidation
    - Load Balancing: Model load distribution, traffic shaping, auto-scaling
    - Edge Deployment: Model optimization for edge devices, federated learning

Modern MLOps for AI (5 Hours)

- Model Lifecycle Management (2 Hours):
    - Experiment Tracking: MLflow, Weights & Biases for AI experiments
    - Model Registry: Version control, staging environments, approval workflows
    - Data Versioning: DVC, data lineage tracking, dataset management
    - Pipeline Orchestration: Kubeflow, Apache Airflow for AI workflows
- LLM-Specific MLOps (2 Hours):
    - LLM Deployment: Serving large models, quantization, distributed inference
    - Prompt Management: Version control for prompts, A/B testing prompts
    - Fine-tuning Pipelines: Automated fine-tuning, model comparison, selection
    - Cost Optimization: Token usage tracking, model efficiency monitoring
- Containerization & Orchestration (1 Hour):
    - Docker for AI: Multi-stage builds, GPU support, model artifact management
    - Kubernetes: Pod scheduling, resource quotas, horizontal pod autoscaling

    - Service Mesh: Istio for AI microservices, traffic management, security

Monitoring & Maintenance (5 Hours)

- AI Model Monitoring (2.5 Hours):
    - Performance Metrics: Accuracy, latency, throughput, resource utilization
    - Data Drift Detection: Statistical tests, feature distribution monitoring
    - Model Drift Detection: Prediction distribution changes, concept drift
    - Alerting Systems: Threshold-based alerts, anomaly detection in metrics
- Production AI Challenges (2.5 Hours):
    - Model Degradation: Causes, detection, mitigation strategies
    - Bias Monitoring: Fairness metrics, demographic parity, equalized odds
    - Explainability in Production: SHAP integration, model interpretation APIs
    - Security: Model robustness, adversarial attacks, input validation
    - Compliance: GDPR, AI Act, audit trails, model governance

🛠️ Practical Exercises:

1. Complete MLOps Pipeline: Build end-to-end MLOps system for AI model with experiment tracking, deployment, and monitoring
2. LLM Production System: Deploy and scale large language model with proper resource management and cost optimization
3. AI System Architecture: Design complete architecture for multi-modal AI application with scalability and reliability considerations
4. Monitoring Dashboard: Create comprehensive monitoring system for production AI models with automated alerting
5. CI/CD for AI: Implement full CI/CD pipeline for AI application with automated testing, deployment, and rollback capabilities

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Module 9: Capstone Projects (15 Hours)

🎯 Learning Objectives:

- Integrate all learned skills into comprehensive AI applications
- Demonstrate end-to-end AI system development capabilities

- Build portfolio projects showcasing diverse AI technologies
- Practice presenting AI solutions to technical and business stakeholders

📋 Detailed Project Options:

Project 1: Generative AI Marketing Assistant (15 Hours)

- Problem Statement: AI system that generates personalized marketing content across multiple channels
- Technical Requirements:
    - Content Generation: Fine-tuned LLM for brand-specific copywriting
    - Multimodal Capabilities: Text + image generation for social media posts
    - Personalization Engine: User segmentation and content customization
    - Performance Optimization: Real-time generation, cost-effective inference
- Implementation Details:
    - LLM Fine-tuning: Domain-specific dataset creation and model customization
    - RAG Integration: Brand guidelines and product information retrieval
    - API Development: FastAPI endpoints for content generation
    - Frontend: Streamlit dashboard for marketers to generate and review content

Project 2: Autonomous Retail Checkout System (15 Hours)

- Problem Statement: Computer vision system for automated product recognition and checkout
- Technical Requirements:
    - Object Detection: Real-time product identification and counting
    - Anti-fraud Measures: Detecting attempts to game the system
    - Edge Computing: Running inference on in-store hardware
    - Integration: Payment processing and inventory management
- Implementation Details:
    - Custom Dataset: Product image collection and annotation
    - Model Training: YOLO fine-tuning for retail products

        - Deployment: Edge optimization with TensorRT/ONNX
        - System Integration: Complete checkout flow with error handling

Project 3: AI Healthcare Diagnostic Assistant (15 Hours)

- Problem Statement: Multimodal AI system for preliminary medical diagnosis
- Technical Requirements:
    - Medical NLP: Symptom analysis from patient descriptions
    - Medical Imaging: Basic diagnostic capabilities for common conditions
    - Knowledge Integration: Medical knowledge base and guidelines
    - Safety: Appropriate disclaimers and human oversight integration
- Implementation Details:
    - Data Processing: Medical text and image preprocessing
    - Model Development: Multi-class classification for conditions
    - RAG System: Medical literature and guideline integration
    - User Interface: Healthcare provider dashboard with clear explanations

Project 4: Multilingual Real-time Translation System (15 Hours)

- Problem Statement: Real-time speech translation for multilingual communication
- Technical Requirements:
    - Speech Recognition: Multilingual speech-to-text conversion
    - Machine Translation: High-quality text translation
    - Speech Synthesis: Natural text-to-speech generation
    - Real-time Processing: Low-latency end-to-end pipeline
- Implementation Details:
    - Pipeline Integration: Whisper + MarianMT + Bark/TTS integration
    - Optimization: Streaming processing, batch optimization
    - User Experience: Web-based interface with real-time feedback
    - Language Support: Multiple language pairs with quality assessment

Project 5: AI Video Content Analyzer (15 Hours)

- Problem Statement: Intelligent video analysis for content summarization and insights
- Technical Requirements:
    - Video Processing: Frame extraction, scene detection, temporal analysis
    - Multimodal Understanding: Audio transcription + visual analysis
    - Content Summarization: Key moments identification and text summarization
    - Insight Generation: Automated tagging, sentiment analysis, topic extraction
- Implementation Details:
    - Video Pipeline: OpenCV for processing, scene boundary detection
    - Multi-modal Fusion: Combining audio, visual, and text features
    - Summarization: Extractive and abstractive summary generation
    - Dashboard: Interactive interface for exploring video insights

📋 Project Execution Framework:

Phase 1: Planning & Research (2 Hours)

- Problem Analysis: Requirements gathering, success criteria definition
- Technology Selection: Architecture design, tool selection
- Resource Planning: Hardware requirements, timeline estimation

Phase 2: Development & Integration (8 Hours)

- Core Implementation: Model training, system development
- Integration: Component integration, API development
- Testing: Unit testing, integration testing, performance testing

Phase 3: Deployment & Optimization (3 Hours)

- Production Deployment: Containerization, cloud deployment
- Performance Tuning: Optimization, monitoring setup
- Documentation: Technical documentation, user guides

Phase 4: Presentation & Portfolio (2 Hours)

- Demo Preparation: Live demonstration setup

- Presentation Creation: Technical and business presentations
- Portfolio Integration: GitHub documentation, video demos

🛠️ Assessment Criteria:

1. Technical Excellence: Code quality, architecture design, performance optimization
2. Innovation: Creative problem-solving, novel approaches, technical depth
3. Business Impact: Practical applicability, value proposition, scalability
4. Documentation: Code documentation, technical writing, presentation skills
5. Demonstration: Live demo capability, error handling, user experience

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Module 10: Career Preparation (5 Hours)

🎯 Learning Objectives:

- Build comprehensive portfolio showcasing AI engineering skills
- Master AI engineering interview processes and technical assessments
- Develop strategic career plan for AI engineering roles
- Create professional network within AI community

📋 Detailed Topics Covered:

Portfolio Development & Professional Branding (2 Hours)

- GitHub Portfolio Optimization:
    - Repository Organization: Clear structure, comprehensive READMEs, documentation
    - Code Quality: Clean, commented, production-ready code
    - Project Diversity: Showcasing different AI technologies and applications
    - Contribution History: Consistent commits, collaboration evidence
- Technical Blog & Content:
    - Technical Writing: Explaining complex AI concepts clearly
    - Project Walkthroughs: Step-by-step implementation guides
    - Industry Analysis: AI trend analysis, technology comparisons

- Professional Profiles:
    - LinkedIn Optimization: AI engineer positioning, skill endorsements, content sharing
    - Resume Crafting: Quantified achievements, relevant keywords, ATS optimization
    - Personal Website: Professional landing page with portfolio showcase

Technical Interview Preparation (2 Hours)

- AI Engineering Interview Types:
    - System Design: Designing scalable AI systems, architecture trade-offs
    - Technical Coding: Algorithm implementation, ML model coding
    - AI Concepts: Deep learning, NLP, CV theoretical understanding
    - Practical Problem-Solving: Real-world AI problem analysis and solution design
- Practice Areas:
    - LLM Integration: Prompt engineering, fine-tuning strategies, RAG implementation
    - Model Optimization: Performance tuning, resource optimization, deployment strategies
    - MLOps Questions: CI/CD, monitoring, model lifecycle management
    - Ethics & Bias: Responsible AI practices, bias mitigation strategies

Job Search Strategy & Networking (1 Hour)

- Target Company Research: Product-based companies, AI-first startups, tech giants
- Application Strategy: Direct applications, referral networks, cold outreach
- Salary Negotiation: Market research, value proposition, negotiation tactics
- Professional Networking: AI conferences, meetups, online communities, mentorship

🛠️ Career Preparation Activities:

1. Portfolio Audit: Comprehensive review and optimization of all projects and profiles

2. Mock Interviews: Technical interviews with feedback and improvement plans
3. Industry Project: Contributing to open-source AI project or kaggle competition
4. Networking Plan: Strategic networking activities and professional relationship building

Complete Open Source Technology Stack

Core AI Development:

- Languages: Python 3.9+, SQL, JavaScript
- ML/AI Frameworks: scikit-learn, XGBoost, TensorFlow, PyTorch
- LLM Tools: Hugging Face Transformers, LangChain, LlamaIndex
- Computer Vision: OpenCV, albumentations, torchvision
- NLP: spaCy, NLTK, sentence-transformers

Generative AI & LLMs:

- Local LLMs: Ollama, llama.cpp, text-generation-webui
- Fine-tuning: PEFT, LoRA, QLoRA, Unsloth
- Vector DBs: ChromaDB, FAISS, Qdrant
- Generation: Stable Diffusion, Whisper, Bark

MLOps & Deployment:

- Experiment Tracking: MLflow, Weights & Biases
- Model Serving: FastAPI, Flask, TensorFlow Serving
- Containerization: Docker, Docker Compose
- Orchestration: Kubernetes, Apache Airflow
- Monitoring: Prometheus, Grafana, MLflow

Data & Infrastructure:

- Databases: PostgreSQL, MongoDB, Redis
- Big Data: Apache Spark, Apache Kafka
- Cloud: MinIO, OpenStack alternatives
- Version Control: Git, DVC

Market Alignment & Career Outcomes

AI Engineer Career Track @ https://udaan.x-fuzion.com/

2025 AI Engineer Salary Trends:

- Junior AI Engineer: ₹12-20 LPA
- AI Engineer: ₹20-35 LPA
- Senior AI Engineer: ₹30-50 LPA
- Principal AI Engineer: ₹45-80 LPA
- AI Architect: ₹60-120 LPA

High-Demand Skills Covered:

- Generative AI & LLMs (45% of AI job postings)
- Prompt Engineering (32% increase in demand)
- Computer Vision (28% of AI roles)
- NLP/Text Processing (35% of AI positions)
- MLOps & Production AI (40% growth in requirements)