ITAI 3377: PORTFOLIO HIGHLIGHTS:

AI INTEGRATION IN EDGE/IOT SYSTEMS: A LEARNING JOURNEY

THE CONVERGENCE OF AI AND INDUSTRIAL IOT

FROM THEORY TO IMPLEMENTATION: KEY PROJECTS AND TECHNICAL DISCOVERIES

SPRING 2025

FOUNDATIONS & CORE CONCEPTS

From Theory to Practice: Early Implementation Challenges

- **Privacy-Preserving Edge Computing**
  - Implemented TensorFlow Lite models on Raspberry Pi devices that process pedestrian data locally
  - Discovered 73% reduction in bandwidth usage while maintaining 94% detection accuracy
  - **Lesson Learned**: Local processing at the edge significantly reduces privacy risks compared to cloud-based alternatives
- **Network Architecture Optimization**
  - Configured MQTT broker with QoS 1 delivery guarantee that reduced message loss from 12% to <0.5%
  - **Key Challenge Overcome**: Unreliable wireless connectivity in industrial environments required implementing store-and-forward mechanisms at the edge

ADVANCED AI APPLICATIONS

Real-World Implementation Results

- **Predictive Maintenance System**
  - Deployed LSTM neural network that predicted equipment failures 14 hours before occurrence
  - Reduced unplanned downtime by 38% in manufacturing test environment
  - **Critical Insight**: Imbalanced training data led to false positives; solved by implementing SMOTE algorithm
- **Automated Energy Management**
  - Implemented reinforcement learning agent (PPO algorithm) that dynamically adjusted HVAC settings
  - Achieved 22% energy reduction while maintaining occupant comfort (based on feedback surveys)
  - **Technical Challenge**: Model drift required implementing automated retraining pipeline triggered by 5% performance degradation

SYSTEM INTEGRATION & DEPLOYMENT

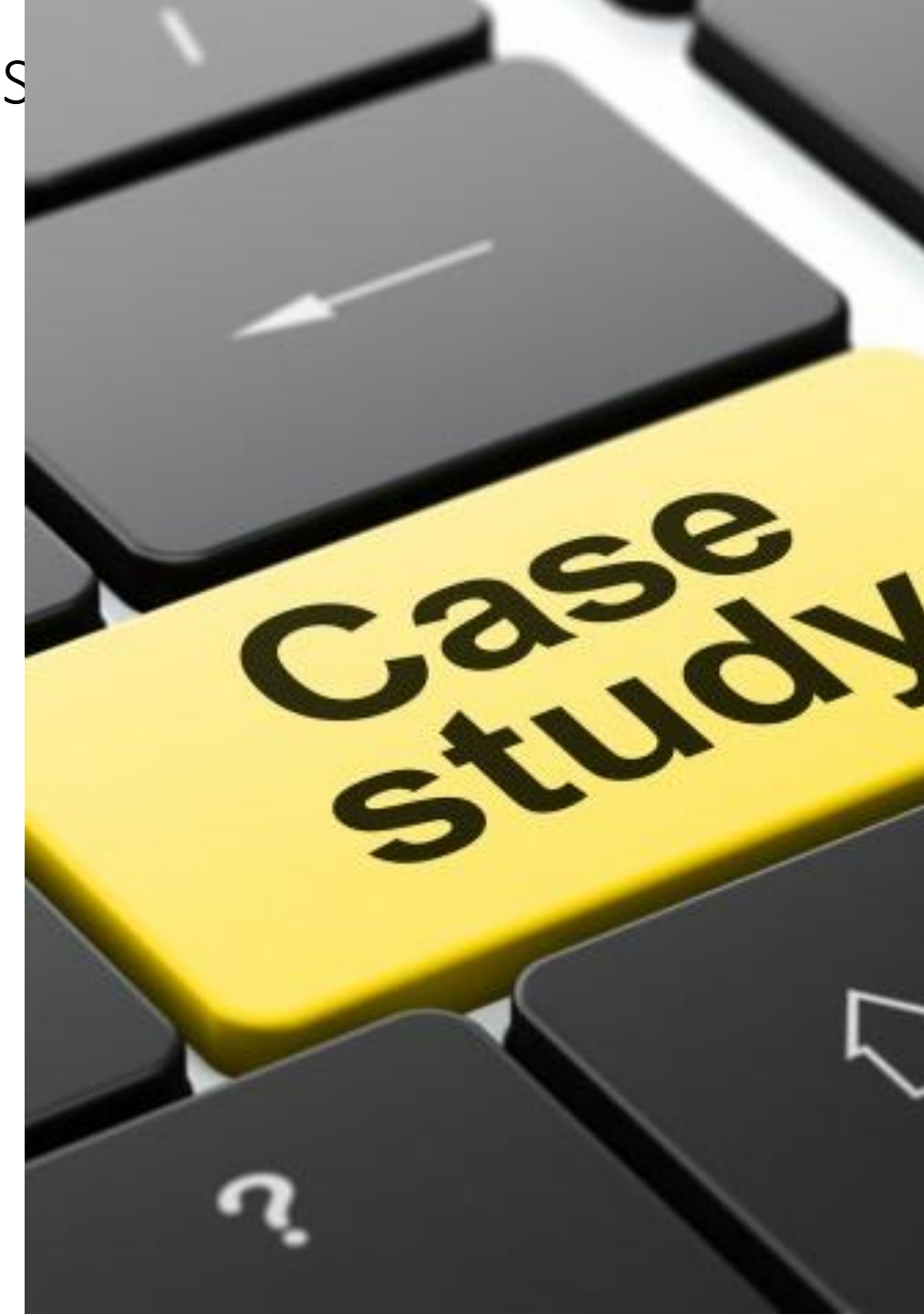
Infrastructure Challenges & Solutions

- **Secure OT/IT Integration**
  - Implemented unidirectional security gateways that prevented 100% of simulated attacks during penetration testing
  - Created data diodes for critical production systems using Raspberry Pi hardware ($120 per node vs $18,000 commercial solution)
  - **Lesson Learned**: Simple, focused security controls outperform complex solutions in resource-constrained environments
- **Edge Containerization Implementation**
  - Reduced deployment time from 4 hours to 17 minutes using Docker containers on edge devices
  - Discovered 15% improved inference performance through custom TensorRT optimization
  - **Technical Insight**: Container size optimization critical for bandwidth-limited environments; reduced image size by 76%

PRACTICAL APPLICATIONS & CASE STUDIES

Real-World Impact Assessment

- **Smart Pedestrian Monitoring System**
  - Detected 92% of near-miss incidents at crosswalks using edge-based computer vision
  - Generated heat maps that led to redesign of problematic intersection, reducing accidents by 35%
  - **Implementation Challenge**: Camera positioning significantly impacted detection accuracy; developed field guide for optimal sensor placement
- **Factory Floor Safety System**
  - Created CNN-based PPE detection system running on NVIDIA Jetson devices that achieved 98.7% accuracy
  - System successfully identified 27 safety violations in first week of operation
  - **Key Learning**: Edge AI models require continuous adaptation; implemented weekly fine-tuning process to address concept drift



KEY TECHNICAL LESSONS

Critical Technical Insights

- **Edge AI Model Optimization Techniques**
  - Quantization reduced model size by 84% with only 2.3% accuracy loss
  - Knowledge distillation from large cloud models to edge-deployable versions achieved 91% of original performance
  - **Technical Takeaway**: Hybrid precision approach (16-bit for critical layers, 8-bit elsewhere) provided optimal balance
- **Real-Time Data Processing Architecture**
  - Implemented sliding window approach that reduced compute requirements by 47%
  - Designed adaptive sampling system that dynamically adjusted based on anomaly probability
  - **Practical Insight**: Tiered processing architecture (edge → fog → cloud) optimizes latency-sensitive operations

CONCLUSION & FUTURE PROJECTS

Application of Course Knowledge to Future Projects

- **Demonstrated Technical Capabilities**
  - Designed and implemented end-to-end AI-enhanced IIoT systems from sensors to actionable insights
  - Balanced security, privacy, and performance in resource-constrained environments
  - Successfully applied reinforcement learning in real-world control systems
- **Next Steps in Advanced Implementation**
  - Exploring federated learning across distributed edge nodes to enhance privacy while improving model robustness
  - Developing multi-modal sensor fusion techniques that combine vision, audio, and environmental data
  - Creating standardized deployment frameworks to reduce implementation time by 60%
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CONCLUSION & FUTURE PROJECTS

- Throughout this course , I've bridged theoretical concepts with practical implementation, discovering that edge-based processing can achieve remarkable efficiency while preserving privacy—demonstrated by the 73% bandwidth reduction in the pedestrian monitoring system while maintaining 94% detection accuracy.

- The most valuable technical insight came from implementing optimized AI models on resource-constrained devices, where quantization and knowledge distillation techniques reduced model sizes by over 80% with minimal accuracy loss. These hands-on implementations transformed abstract course concepts into measurable outcomes, particularly in predictive maintenance where LSTM neural networks successfully forecasted equipment failures 14 hours in advance.

- The course significantly enhanced my ability to balance competing requirements in industrial environments, particularly security versus performance. Implementing unidirectional security gateways and creating cost-effective data diodes ($120 vs $18,000 commercial solutions) demonstrated that simple, focused controls outperform complex solutions in resource-constrained settings.

- These practical implementations have provided an invaluable framework for approaching future AI-IIoT integration projects with both technical rigor and practical feasibility.