



Project Proposal -1-

Integrating LSTM, CNN, and Reinforcement Learning for Adaptive Human-Computer Interaction in Windows Applications

(CNN) والشبكات العصبية الالتفافية (LSTM) دمج الشبكات العصبية طويلة الذاكرة والتعلم التعزيزي لتفاعل الإنسان والحاسوب التكيفي في تطبيقات نظام ويندوز

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الاهداء

(وَأَخِرُ دَعْوَاهُمْ أَنْ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ)

من قال أنا لها .. نالها

وأنا لها وإن أبت رغما عنها أتيتُ بها لم تكن الرحلة قصيرة ولا ينبغي لها أن تكون، ولم يكن الحلم قريبا ولا الطريق كان محفوفاً بالتسهيلات لكنني فعلتها ونلتها.

إلى من شرفني بحمل اسمه .. والذي العزيز رحمه الله إلى النور الذي أثار دربي والسراج الذي لا ينطفئ نوره بقلبي أبداً ، من بذل الغالي والنفيس، واستمدت منه قوتي واعتزاني بذاتي.

إلى نور عيني وضوء دربي ومهجة حياتي .. إلى التي ساندتني، ووقفت بجانبني، وقدمت لي الدعم المتواصل في طريقي، إلى التي وهبتني الحياة والأمل، واحتضنتني قلبها قبل يدها وسهلت لي الشدائد بدعائها، والدتي الحبيبة حفظها الله.

إلى ضلعي الثابت وأمان أيامي، إلى ملهمي نجاحي إلى من شددت عضدي بهم فكانوا لي ينابيع أرتوي منها .. إلى خيرة أيامي وصفوتها إلى قرة عيني وأخواني وأخواتي الغالين

إلى أساتذتي الكرام ممن لم يتوانوا في مد يد العون لنا .. يا من صنعتم لنا المجد.

أهديكم هذا الإنجاز وثمره نجاحي الذي لطالما تمنيته، ها أنا اليوم أتممت أول ثمراته بفضل من الله عز وجل، فالحمد لله على ما وهبني، وأن يعينني ويجعلني مباركة أينما كنت.

1. Abstract

In recent years, the interplay between artificial intelligence (AI) and humancomputer interaction (HCI) has gained considerable traction as researchers strive to move beyond static interface paradigms toward adaptive, predictive and contextaware systems. For instance, Brdnik et al.(2022) provide a comprehensive mapping of how intelligent user interfaces (IUIs) leverage AI in HCI to enhance usability and user experience. Meanwhile, Saudi Arabia is actively positioning itself as a major player in the AI domain, with the Saudi Data & Artificial Intelligence Authority (SDAIA) reporting that the Kingdom is aligning AI adoption with its Vision 2030 goals across investment, infrastructure, talent development and service delivery (SDAIA, 2024). Despite this momentum, many Windowsbased desktop applications (e.g., particularly in the Saudi context) continue to rely on static menu structures, fixed layouts and nonadaptive interaction patterns, leaving significant room for improvement in usability, accessibility and user satisfaction. This proposal explores how AI techniques can be embedded into Windows HCI applications to deliver more adaptive, culturally and contextually relevant interfaces in Saudi Arabia.

2. Project Overview / Introduction

The increasing improvements in the field of Artificial Intelligence (AI) have generated innovative avenues for the development of intelligent, adaptive, and user-centered interfaces in the Human-Computer Interaction (HCI) field. However, most Windows applications, especially the ones that are commonly used in the Kingdom of Saudi Arabia, are based on static interaction behaviors that are unresponsive to the user activity, preference, and need. This work therefore proposes a novel AI-HCI hybrid model using Long Short-Term Memory (LSTM) networks for prediction of interaction sequences, Convolutional Neural Networks (CNN) for GUI component identification, and Reinforcement Learning (RL) for the interfaces' adaptation.

The framework will be tested using real-world GUI data and then conceptually applied to four primary systems being utilized in Saudi Arabia, including Microsoft Excel with an Arabic GUI, the e-Government services offered via Absher, the Tamm vehicle e-services system, and university e-learning platforms within Saudi Arabia. Such research is relevant to and fulfils the needs of digitization outlined for Saudi Arabia's Vision 2030.

2.1 Problem Statement

The core problem statement is that existing Windows desktop applications in Saudi Arabia largely lack adaptive, AI-driven interaction capabilities. These limitations manifest in longer task completion times, interface inflexibility, and reduced user satisfaction, especially given the diversity of user profiles (language, culture, accessibility). Current research in AIHCI has focused more heavily on web and mobile platforms and tends to apply singular AI techniques (e.g., machine learning for recommendations) rather than integrated frameworks combining sequence modelling, GUI element recognition and reinforcement learning for desktop GUIs.

Therefore, the research question is: *How can AI be designed and applied to Windows HCI applications in Saudi Arabia to produce adaptive, user-centered interfaces that improve usability, accessibility, and user satisfaction compared with traditional nonadaptive approaches?*

2.2 Research Scope

The scope of the research is defined as follows: the focus is exclusively on Windows desktop applications rather than mobile or web platforms. The study emphasizes AI-driven adaptive interface design (rather than backend or purely aesthetic changes). Evaluation will be conducted on public datasets and simulated user scenarios (rather than a full live deployment in Saudi organizations at this stage). While the model will be contextualized for Saudi Arabia (e.g., Arabic language, cultural norms), the primary evaluation data may not originate from Saudi users.

2.3 Research Significance

The significance of this research lies in filling multiple gaps: it addresses a platform-specific underexplored area (Windows desktop HCI), applies AI-based techniques within HCI rather than a single method, provides empirical evaluation using usability as well as predictive metrics, and offers relevance to Saudi Arabia's digital transformation agenda by suggesting adaptive interfaces suited for local language, culture and accessibility needs.

3. Project Goal

The aim of the study is to design, implement, and evaluate an intelligent adaptive HCI model for Windows applications in Saudi Arabia that enhances usability, efficiency, and user satisfaction.

3.1 Specific objectives

The aims of the project are outlined below:

- 1) Create a hybrid AI-HCI model that integrates LSTM, CNN, and RL techniques, specifically designed for Windows desktop applications.
- 2) Develop the model using publicly accessible GUI interaction datasets, and then simulate its functioning on four Windows applications in Saudi Arabia.
- 3) Enhance the accuracy for LSTM and CNN predictions, while ensure that the time taken to complete tasks in the simulation reduces by 20% or more compared to traditional static interfaces.
- 4) Incorporate explainability through SHAP and LIME, while ensuring the model remains clear and complies with regulatory requirements.
- 5) Evaluate the model with HCI metrics such as SUS, NASA-TLX, and task completion times, while comparing it to baseline non-adaptive interfaces.
- 6) Ensure that the model aligns with Saudi cultural, linguistic, and regulatory standards.
- 7) Provide actionable insights for implementing the model within Saudi government, educational, and business environments.

4. Approach /Methodology

The study employs a quantitative experimental approach that integrates deep learning with RL methods to create an adaptable HCI model specifically for Windows applications in Saudi Arabia.

4.1 Data Collection

The study utilizes four publicly available datasets:

- RICO Dataset (2017) for GUI screenshots and interaction logs.
- Microsoft GUI Dataset (2020) for Windows interaction events.
- Open-UI Dataset for UI component recognition.
- GazeHCI Dataset for attention modeling.

They will be employed alongside simulated interaction records to analyze user actions in four Windows-based applications in Saudi Arabia: Excel-Arabic, Absher, Tamm, and Blackboard Ultra.

4.2 Data Processing

Data preprocessing will include:

- Normalization and encoding of interaction sequences for LSTM.
- Resizing and augmentation of GUI screenshots for CNN.
- Feature extraction for RL state representation.

4.3 Model/Method Selection

The proposed model integrates:

- LSTM for sequential user interaction prediction.
- CNN (ResNet-50) for GUI element and layout recognition.
- RL (DQN/PPO) for adaptive interface decision-making.

4.4 Testing and Evaluation

The performance will be evaluated using four approaches:

- Accuracy, precision, recall, and f1-score for LSTM and CNN.
- Task completion time (TCT) and error rate (ER) reduction.
- System usability scale (SUS) and NASA-TLX for user experience.
- Comparative analysis against baseline static interfaces and existing literature.

5. Project Steps and Timeline

The proposed study will be completed in 10 weeks' timeline:

Week	Phase	Description
1	Data Collection & Setup	Collect and preprocess RICO, Open-UI, and Microsoft GUI datasets. Set up Python/TensorFlow/PyTorch environment.
2	Data Preprocessing & EDA	Clean data, perform exploratory analysis, and prepare sequences (LSTM) and images (CNN).
3	Model Implementation - LSTM & CNN	Build and train LSTM for sequence prediction and CNN for UI recognition.
4	Model Implementation - RL Integration	Develop RL agent (DQN/PPO) and integrate with LSTM+CNN embeddings.
5	Model Training & Hyperparameter Tuning	Train integrated model, apply cross-validation, and optimize hyperparameters.
6	Explainability Integration	Implement SHAP and LIME for model interpretability.
7	Evaluation & Performance Testing	Test model on simulated Saudi system logs. Calculate accuracy, TCT, SUS scores.
8	Comparative Analysis & Benchmarking	Compare results with baseline and literature. Analyze cultural and regional implications.
9	Compliance & Documentation Check	Ensure alignment with Saudi regulatory and cultural context. Finalize thesis chapters.
10	Report Preparation & Finalization	Compile results, complete thesis writing, and prepare presentation.

6. Expected Results

The study is expected to produce:

- A new hybrid AI-HCI model that combines LSTM, CNN, and RL for Windows applications.
- Enhanced HCI metrics, like ≥87% LSTM precision, ≥92% CNN precision, and a ≥20% decrease in task completion times.

- Insights into cultural and regional aspects related to adapting Arabic interfaces and the behavior patterns of Saudi users.
- A model for flexible HCI that may be applied to other Windows applications in Saudi Arabia.
- Academic contributions, such as the first integrated LSTM-CNN-RL model for HCI in Saudi Windows applications; along with a fresh annotated dataset of simulated Arabic user interface interactions.
- Practical implications, which include improved usability for Saudi e-government, educational systems, and business applications.

7. Resources Needed /Resources Required

In order to effectively finish this project, it will be crucial to have the necessary resources at various phases of development, training, and assessment:

7.1 Tools and Software

- Python, TensorFlow, PyTorch, OpenCV, Scikit-learn, Stable-Baselines3
- Jupyter Notebook, Google Colab Pro
- Matplotlib, Seaborn for visualization

7.2 Dataset

- RICO (2017), Open-UI, Microsoft GUI Dataset (2020), GazeHCI
- Simulated logs for Saudi systems (Excel-Arabic, Absher, Tamm, Blackboard Ultra)

7.3 Computing Resources

- GPU-enabled environment (NVIDIA T4/A100 via Colab)
- Local testing on Intel i7/32GB RAM/RTX 3060

7.4 Expert Guidance

Thesis Supervisor: Dr. [Khaled Eskaf]

8. Literature Review

The studies listed below constitute the essential literature and earlier research that shape the progression of this project. They provide theoretical context, methodology, and benchmarking information for an adaptive HCI model utilizing AI methods:

Study	Methodology	Dataset	Results	Limitations
Brdnik et al. (2022)	Systematic mapping, literature review	Not specified (review of existing studies)	Identified key AI techniques used in IUIs, trends in adaptive & context-aware interfaces	Focused on IUIs in general; not specific to Windows or Saudi context
Mohseni & Akbari (2025)	Empirical study, experimental evaluation	Simulated user interaction data	14% reduction in completion time, 22% increase in engagement vs. static interfaces	Small-scale experiment; limited to dashboard interfaces
Shrestha et al. (2022)	Literature review, comparative analysis	Not applicable (review paper)	Summarized benefits & implementation challenges of adaptive menus	Theoretical; no empirical validation
Wang et al. (2024)	Systematic literature review	Not applicable (review paper)	Identified measurable improvements in task performance & user satisfaction with AUIs	Healthcare; not generalizable to other domains
Al Shahrani et al. (2024)	Survey research, quantitative analysis	Survey responses from medical students	High awareness but moderate readiness; positive attitude toward AI in healthcare	Limited to medical students; not HCI-focused
SDAIA (2024)	Report, policy analysis	National AI adoption data	Progress in AI infrastructure, talent development, & cross-sector integration	Descriptive; no experiments
Mishra et al. (2025)	Conceptual analysis, literature synthesis	Not applicable (conceptual paper)	AI is reshaping UX design, interaction models, & cognitive computing	Broad scope; no empirical or technical depth
Miraz et al. (2021)	Literature review, theoretical framework	Not applicable	Plasticity enables UIs to adapt across devices & user contexts	No implementation or user testing
Xu (2024)	Chapter review, conceptual discussion	Not applicable	AI/ML capabilities are becoming integral to UX workflows	Theoretical; no experimental validation
Jiang et al. (2024)	Literature review, research agenda formulation	Not applicable	Proposed research themes: collaboration, symbiosis, transparency in HAI	Agenda-setting; no primary data or experiments

Study	Methodology	Dataset	Results	Limitations
Sharma & Shrestha (2024)	Literature review	Not applicable	Highlighted importance of interpretability, ethics, & user control in AI systems	Broad review; no focus on specific platforms or cultures
Raees et al. (2024)	Systematic literature review	Not applicable	Trends show shift from explainability to interactivity & collaboration	Review-based; no original empirical work
Carrera-Rivera et al. (2024)	Framework development, case study implementation	Smart device interaction logs	Framework improved recommendation precision & context awareness	Focused on mobile/smart devices; not Windows desktop
Nguyen et al. (2024)	Systematic survey of 53 publications	Not applicable	Identified common design patterns & evaluation methods for explainability interfaces	Review-only; no new models or datasets
Huang et al. (2024)	Exploratory study using LLMs for persona generation	Generated personas via ChatGPT	LLM-generated personas were realistic & useful for adaptive UI design	Limited to persona generation; no full system evaluation
Kosch et al. (2023)	Experimental study with AI interface	Word puzzle task logs	Belief in AI support improved performance even without real AI	Did not evaluate real AI; limited to placebo effect
Bieniek et al. (2024)	Trend analysis, literature synthesis	Not applicable	Generative AI enables rich multimodal interactions across platforms	Emerging area review; no empirical deployment
Degen & Ntoa (Eds.) (2023)	Conference proceedings compilation	Various across papers	Diverse papers on human-centered AI, explainability, & collaboration	Collection of works; not a single study
Alkatheiri (2022)	Book, comprehensive overview	Not specified (textbook)	Covered AI techniques for adaptive, predictive, & context-aware UIs	General reference; not empirical
Consultancy-ME (2024)	Report, market analysis	Industry reports	Highlighted Saudi investments & initiatives in AI across sectors	Non-academic source; limited technical detail
Dix et al. (2004/2020)	Textbook, foundational principles	Not applicable	Core HCI concepts, design principles, & evaluation methods	Educational resource; not a research study
Findlater & Gajos (2009)	Design research, evaluation framework	Not specified	Proposed methods for designing & evaluating adaptive UIs	Dated; may not reflect current AI trends
Smith et al. (2020)	Experimental, CNN+LSTM modeling	Public GUI logs	Improved prediction accuracy by 15% over baselines	Small dataset; limited generalizability

Study	Methodology	Dataset	Results	Limitations
Zhang et al. (2025)	RL simulation, adaptive UI design, Experimental, LSTM modeling	Simulated GUI interactions, Sequential task logs	RL enabled adaptive behavior & increased usability, LSTM accurately predicted next user actions in sequences	Not tested on real users, Limited to LSTM; no integration with CNN or RL
Nasirian et al. (2017)	NLP+ML implementation, user testing	Local user logs (Saudi government app)	High user satisfaction & task efficiency with voice interface	Limited scope; single application focus
Yang et al. (2018)	Review, mapping study	Not applicable	Mapped ML techniques to HCI design & evaluation practices	Broad; lacks Arabic support & RL integration
Al-Fraihat et al. (2020)	Survey research, usability evaluation	Survey data from e-learning users	Identified usability issues in Arabic e-learning platforms	No AI or adaptive techniques included
Alhassan & Altamimi (2023)	Usability testing, heuristic evaluation	User testing with Arabic Excel	Found navigation & toolbar challenges in Arabic Excel	No AI-driven solutions proposed
Lv et al. (2022)	Systematic literature review	Not applicable	Reviewed DL approaches for modeling user interactions	Review-only; no new dataset or model
Aloboud et al. (2020)	Usability testing, user studies	Absher platform logs (simulated/real)	Absher had good usability but areas for improvement in navigation	Limited to Absher; no adaptive AI integration
Alamri & Almoaiqel (2021)	Mixed-methods evaluation	E-learning system logs, surveys	Identified gaps in accessibility & user guidance	No AI adaptation; traditional HCI only
Chen et al. (2020)	Experimental, CNN modeling	UI screenshot datasets	High accuracy in UI element detection & classification	Not tailored for Arabic or complex GUIs
Bojarski et al. (2016)	Deep learning, simulation	Driving datasets (e.g., NVIDIA)	Demonstrated feasibility of end-to-end autonomous driving	Domain-specific (automotive); not HCI-focused
Goodfellow et al. (2016)	Textbook, theoretical foundations	Not applicable	Comprehensive coverage of DL architectures & algorithms	General ML reference; not HCI-specific
Deka et al. (2017)	Dataset creation, annotation	RICO mobile UI dataset	Large-scale annotated dataset of mobile UI screens & interactions	Mobile-only; not directly applicable to desktop
Alannsary (2025)	Usability testing, task analysis	Tamm system logs	Tamm had moderate usability with room for workflow optimization	No AI or adaptive interface evaluation

Study	Methodology	Dataset	Results	Limitations
Krizhevsky et al. (2012)	Experimental, CNN architecture	ImageNet dataset	Dramatically improved image classification accuracy	Computer vision focus; not HCI-specific
Mnih et al. (2015)	Experimental, DQN algorithm	Atari game environments	Achieved human-level performance on multiple Atari games	Gaming context; not adapted to HCI tasks
Sun et al. (2024)	Systematic review	Not applicable	Summarized RL applications in adaptive UIs	Review-only; no original implementation
Microsoft (2020)	Guidelines, design documentation	Not applicable	Provided best practices for Excel UI design & interaction	Non-academic; descriptive only
Sutton & Barto (2018)	Textbook, RL fundamentals	Not applicable	Comprehensive introduction to RL theory & algorithms	Educational; not an empirical study
Alhusseini & Abuanza (2024)	Review, policy analysis	Not applicable	Outlined progress & challenges in Saudi digital transformation	Broad overview; not HCI or AI-specific

9.1 Overview of Existing Research

Current investigations in AI-HCI mainly concentrate on web, mobile, or general adaptive user interfaces, paying little attention to Windows desktop applications or the context of Saudi Arabia. Research works like those by Brdnik et al. (2022) and Mohseni & Akbari (2025) emphasized the possibilities of AI-based adaptation but fail to consider factors that are specific to platforms or cultural elements.

9.2 Key Research Gaps

- Platform, where limited research focused on adapting Windows desktop graphical user interfaces.
- Regional/Cultural, where there has been no research on adapting Arabic interfaces or understanding Saudi user behavior.
- Technical Integration, where there has been minimal work that merges LSTM, CNN, and RL for human-computer interaction adaptation.
- Evaluation, where only a handful of studies have linked technical metrics with usability and cultural assessments.

9.3 Research Justification

This proposal addressed the gaps by introducing a Windows-based, culturally flexible AI-HCI model designed specifically for Saudi Arabia, combining various AI approaches, and assessing both functionality and user experience.

10. Limitations and Risks

- Lack of data, since there is no actual dataset for Saudi Windows interactions; only public datasets and simulations are available.
- Cultural oversimplification, where the behavior of simulated users might not accurately reflect the subtle cultural aspects of Saudi Arabia.
- Technical difficulties, where the combination of LSTM, CNN, and RL makes the model more complicated and takes longer to train.
- Regulatory compliance, which involves making sure that the concepts align with Saudi Arabia's digital governance standards.

10.1 Risk Mitigation Strategies

- Implement multi-dataset validation to enhance generalization.
- Seek advice from HCI specialists for cultural and behavioral verification.
- Utilize modular testing to confirm that each AI part operates properly.
- Ensure the framework is in accordance with Saudi digital transformation standards.

11. Conclusion

This proposal presents a new hybrid AI-HCI model for flexible Windows applications in Saudi Arabia. By integrating LSTM, CNN, and RL techniques. Thus, this study seeks to enhance interaction effectiveness, ease of use, and user satisfaction in government, educational, and business systems. The findings provide both theoretical and practical benefits, pursuing the objectives of Saudi Arabia's Vision 2030 and promoting progress in adaptive HCI.

12. Documentation Tools

- Microsoft Word for report writing and structuring project documentation.
- PowerPoint for preparing the final presentation or defense.

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