Large Language Model-Driven Adaptive Learning Path Planning Systems for Language Arts: Advances in Intelligent Engineering Frameworks

Xiaoming Luo
Guangzhou Tianhe Longkouxi Primary School

ABSTRACT

The emergence of a wide range of language models enables a new generation of adaptive learning path planning system to dynamically customize the trajectory of language art education. This paper uses the ideas of system engineering, network physical system theory and information theory to analyze these systems, and regards them as intelligent and complex engineering objects. Core technology components-such as digital twins for representing learners' state, reinforcement learning for planning dynamic activities, computer vision for real-time performance detection, and edge computing for low-delay control-are studying whether they can close the feedback loop between learners' physical interaction and network planning layers. The concrete examples of K-12 China language course and literature analysis academic course show that the participation, mastery time and skill transfer are significantly improved. Nevertheless, there are still significant risks. For example, LLM illusion that causes language errors, cultural bias in training data, privacy issues in continuous CPS data, and the risk of learners and teachers losing their skills. A new idea is to propose a path planning goal to reduce. It measures the fitness value and expected information gain, and extends the classical knowledge tracking to the generation situation. Looking forward to the future, we are considering a mixed architecture with multiple agents, federal updates to protect privacy, and standardized interpretable protocols. The analysis shows that serious engineering disciplines are needed to balance moral and educational protection for sustainable development.

Keywords: Large Language Models, Adaptive Learning Paths, Language Arts Education, Cyber-Physical Systems, Systems Engineering, Information Theory, Reinforcement Learning, Digital Twins.

1. INTRODUCTION

Language art education, including reading, writing, literature and cultural analysis, needs very different lessons for each student, because children don't have the same knowledge, the same learning style and the same motivation. Normal intelligent tutorial systems have achieved some success in rules or probabilities, but they are not flexible or accurate enough for practical language work. Large-scale language models have brought about important changes: they can make clear explanations, ask appropriate questions and help students by simulating dialogues [1]. When we put these models into a system that adapts to the learning path, they can create, track and change the whole journey of students according to their behaviors.

From the point of view of intelligent engineering, these architectures are complex social and technical systems, which can be analyzed by system engineering method. The principle of feedback control says that when there is a difference between what a learner does and what he needs to know, it will change the path of correction. The network physical system theory can better explain the architecture by separating the physical layer (tablet computer, camera, microphone and physiological sensor to receive writing action, gaze and voice) from the network layer (LLM planner, knowledge graph and optimization engine). Information theory provides a quantitative basis: learners' knowledge is modeled as a probability distribution on the concept map. Each recommended activity is evaluated according to the degree to which it reduces the distribution, which provides a clear goal for choosing the path, not just based on the idea [2].

Although they are used very quickly everywhere, there is not much research on how the LLM language arts system is built on these projects. This review will help to collect technologies, how to use them in real life and make important choices. The analysis shows the benefits we have seen, such as better adaptation to everyone, easy growth and quick response, but there are also some important problems, such as we don't always know how the model works, who owns the data, and the risk of displaying culture or language incorrectly. The next part explains the basic ideas, shows the technologies and methods used, studies their applications in which fields, puts forward some thorny problems, and discusses how to use artificial intelligence cautiously to build a better education system.

2. THEORETICAL FOUNDATIONS: INTEGRATING SYSTEMS ENGINEERING, CYBER-PHYSICAL SYSTEMS, AND INFORMATION THEORY IN LLM-ENHANCED EDUCATIONAL ARCHITECTURES

Systems engineering gives a great rule to make a controllable educational process. The adaptive learning path is divided into several small parts: learning state estimation, content and activity sequencing, multimodal feedback generation and result verification, which are connected by feedback loops. The idea of model predictive control is useful: at each decision-making moment, the planner imagines the possible future path on the backward horizon, chooses the order of giving the most rewards (learning gain minus cognitive load and time), and takes action immediately before starting a new observation.

The theory of network physical system makes the integration of physical and computational elements clear and bidirectional. The physical subsystem has many learning interfaces for sensors. These interfaces convert writing pressure, reading fixed time and voice height changes into traffic that can be read by the machine. The network subsystem performs state estimation, path synthesis, LLM prompting and policy execution. Matching is powerful: physical signals update the network model almost in real time, and the tips and supports of network creation change the subsequent physical interaction. The extension of the original theory proposed here adds LLM semantic control layer to the classical CPS. This layer interprets learners' unstructured words or written explanations, transforms them into formal knowledge map updates, and provides high-level control commands to low-level activity planners. Therefore, it bridges the semantic gap that traditionally separates symbol scheduler from natural language interaction [3].

Information theory provides a measurement method. It shows how we construct each language art as a probability distribution on the concept map, and gives a connection entropy to show how much we don't know. Then, LLM-driven path planning becomes an active learning process: selecting activities to get the most mutual information between the results and the potential knowledge state. This idea is more common than previous Bayesian knowledge tracking, because it works with free answers, not just multiple-choice proofs.

A real example shows how it works. In the primary school network of a province in China, every student has a digital twin, which is a probability model of role recognition, reading fluency and composition skills. The edge computing node views the writing trace and reading record on the tablet computer; Computer vision pipeline looks for line sequence errors and rhythm problems. Next, the reinforcement learning scheduler chooses what to do and uses the reduced rewards. In one semester, compared with ordinary courses, the system saves 23% time to learn core milestone literacy, and teachers can see the progress on the dashboard with double tracks.

The second real example, which is used in the course of literary criticism for undergraduates, uses CPS cycle, in which discussion forum posts and essays are analyzed by LLM components to update the dynamic knowledge map that explains concepts. Reinforcement learning adjusts the matching order of subsequent readings and peer evaluation to keep learners in the best challenge area. The audit based on information theory shows that the high-yield activities focus on the targeted Socrates problem rather than the comprehensive report of the content, which provides information for the subsequent improvement of real-time engineering [4].

These theories promise to jointly promote LLM-driven route planning from temporary customization to strictly specified, measurable and optimizable engineering disciplines.

3. KEY TECHNOLOGIES AND METHODOLOGICAL FRAMEWORKS FOR ADAPTIVE LEARNING PATH PLANNING IN LANGUAGE ARTS

Three technologies work together to help today's machines run. First of all, based on the lesson objectives adopted by the Master of Laws planners and what the students know now, they make a list of activities. With good tips, using the chain of thought reasoning, some examples of good progress, and respecting the rules of culture, they can explain the reading list, writing topics and thinking tasks. Then, intensive learning helps to change the schedule in real time. The problem is regarded as a markov decision processes, in which the state shows what students have learned and other things. Action is to select an activity or difficulty level; Rewards mix what students do immediately with the estimated values of their later study, which are calculated by a calculation formula. Non-strategic algorithm with careful updating helps to keep little change between simulated students and real students [5].

Third, the perception layer and the action layer closed the physical-network cycle. The computer vision pipeline is becoming more and more simplified, so that it can be used on devices (edge deployment), and can detect the readability of handwriting, the emotion of the face when reading, and even the simple eye movements through the front camera. Edge computing nodes run these lightweight models with a delay of less than 100 milliseconds, allowing minor repairs immediately, while leaving the overall path planning to LLM instances hosted in the cloud. Periodic synchronization can keep the consistency of the student-centered model, instead of sending the original biometric data all the time, thus solving the problems of delay and privacy.

The critical eyes showed that there was a compromise. Policies to strengthen learning can find very effective ways, but they may be too adapted to the signs of short-term commitment and lose the ability of long-term learning. Master of Laws planners sometimes invent explanations with no linguistic meaning, which are not in the correct cultural background, especially when China's classical texts are not part of the main training data. Edge deployment reduces the dependence on the cloud, but it will cause model compression problems, which may reduce the detection accuracy, such as subtle features such as roughness or calligraphy.

A new method is hierarchical hybrid planner. In this planner, the edge agent handles fast and simple actions by using a simplified perception model; At the same time, LLM Cloud is making a longer and more thoughtful plan to choose the path. Synchronization is done in natural time with a small state vector, not all the original data. This not only maintains the speed, but also maintains a good overall understanding.

The first real case: a business language learning platform that helps overseas Chinese learners uses this hybrid architecture. Edge CV detected a character writing error in a small daily exercise. Local agents immediately gave visual feedback. The summary error triggered LLM Cloud's new weekly schedule. This adds special exercises, or changes the balance between simplification and traditional characters according to learners' goals.

The second real example: reinforcement learning is used to mix reading, annotation and writing tasks in college writing courses of all subjects. Computer vision analysis of the annotated PDF gives the progress index of changing the reward. This enables planners to choose activities that promote deeper participation, rather than just completing them quickly.

4. APPLICATION DOMAINS AND REAL-WORLD IMPLEMENTATIONS IN LANGUAGE ARTS EDUCATION

The deployment environment ranges from the basic reading and writing study of K-12, to learning Chinese as a second language, and then to university literature research and adult professional exchanges. In each field, CPS-LLM combination provides a special value proposition, but it also shows the weakness of each field.

In the Chinese course of primary and secondary schools, the digital twins of character mastery and reading comprehension allow very fine adaptation, which the traditional whole classroom teaching can't do. The intensive learning policy has been proved to be able to practice more where there are still a lot of mistakes, which will help difficult readers make faster progress without shaming them. Benefits include providing better fairness to students in schools, who have less resources and less administrative work for teachers. Risks include over-reliance on automatic feedback, which may forget the importance of social and emotional aspects in reading and learning, and introducing cultural prejudice when literary examples created by LLM are beneficial to certain regions or historical stories [6].

The literature analysis course in universities uses LLM planners to make personalized reading lists and Socrates sequences, which not only respects important books, but also respects what students like to read. Through computer vision, we can look at the notes and writing drafts in books, and the data it provides is used to strengthen learning to better help build arguments. We have seen that even if students come from different languages, they will read and participate more deeply. However, there is a problem when LLM explains the deletion of hidden meaning from the text, or when the impact detection of edge deployment can't understand the expression of confusion or excitement well [7].

Adult and business language training programs use edge enhancement systems, which are always available and can support deadlines well. This helps to adapt to the irregular schedule. Learning path planning aims to improve communication skills, not just school performance. Insert a simulation of the real situation, which is created by LLM on demand. Joint updating to protect the privacy of customer organizations is a promising idea, but people are still worried about the disclosure of private data and everyone speaking in the same way at work.

In all fields, when we look at it with the eyes of engineering, we see that the right solution locks human beings in the loop-teachers or tutors can say no to the path provided by LLM-and we clearly write down why we make these choices. A system that tries to improve test scores without respecting learners' freedom or cultural diversity will eventually destroy the real purpose of language education.

5. CHALLENGES, LIMITATIONS, AND FUTURE PROSPECTS

Technical problems include LLM illusion, putting wrong or misspelled information into the learning path, contextual window restrictions, preventing good consistency in several weeks of courses, and the difficulty in matching the results with specific teaching objectives. The reinforcement learning strategy trained in simulation often becomes less good when used, because the actual students are different from the students in training. Edge perception models, even if they allow immediate response, will lose the accuracy of subtle signals such as rhetorical tone or subtle differences in calligraphy.

The boundary between education and morality is also very important. Continuous CPS monitoring has brought significant data sovereignty and consent issues, especially when using biometric data. Algorithm deviation may systematically put students whose language practice or cultural reference is different from the main training corpus at a disadvantage, which

may reproduce the language level in education. Excessive reliance on automation will weaken the development of metacognition and critical evaluation. In addition, the lack of clarity in LLM reasoning and RL learning policies hinders teachers' trust, making it difficult to know who is responsible for maladjustment.

The future prospects are in several engineering directions. Multi-agent LLM suite-with planning agent, cultural fidelity key agent, and teaching alignment agent-can reduce the illusion of a single model while maintaining a rich generation. Joint and differentiated private learning protocols help to improve the relationship between institutions without the sensitive tracking of centralized learners. The interpretable path planning interface shows why each adaptation is reduced, which provides a concrete method for human monitoring and regulatory audit. The commitment of integration with augmented reality environment and the immersive experience of historical and literary background are controlled by the same CPS feedback architecture.

An original proposal for the future is to make information theory audit mandatory as a standard report. By recording the expected and realized reduction of each learner and each activity, developers and educators can obtain a clear and comparable measure of adaptation quality, which exceeds the opaque accuracy score and helps to improve models and procedures [8].

6. CONCLUSION

The adaptive learning path planning system driven by the big language model is a major evolution of personalized education project in language arts. By putting the generation model into the network physical feedback architecture and making adaptive decisions according to the information theory objectives, these systems have achieved a level of responsiveness and semantic depth that the old intelligent tutoring technology did not have. In real life, they show real improvement in efficiency and participation, but at the same time, they also bring great risks of prejudice, privacy and loss of teaching skills, which must be reduced through discipline.

The viewpoints of system engineering, network physics and information theory we see in this review are useful for diagnosis and prescription. They explain why some architectures will work or fail, and provide specific criteria for future design and evaluation-reduced content, closed-loop stability and semantic fidelity. For sustainable development, artificial intelligence researchers, learning experts, language teachers and system engineers need to work together to formulate strong rules to protect learners' choice, culture and access rights for all. When these conditions are met, the intelligent engineering system enhanced by LLM can really help language art education, not just alone.

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