Research on Curriculum Content Reconstruction and Teaching Practice of Communication Electronic Circuits Based on Knowledge Graph

Ting Liu*

City Institute Dalian University of Technology, Dalian, 116102, China
**Corresponding author: liutingtara@126.com*

Abstract: *The general attributes of the knowledge system for the Communication Electronic Circuit course are dense concepts and complex logical associations. The traditional linear chapter structure cannot show all the connections among the knowledge points, and the speed of content updates is slow in the face of changes in technology. Knowledge graph technology is used to organise the courses in a new way; an ontology model is employed to build a hierarchy of subject knowledge, extract semantic relationships among knowledge points, integrate various teaching materials from different places, and construct a computable and navigable course knowledge graph. Then, it will organise the modules and topology of the knowledge system, design cross-chapter integration paths, and plan navigation sequences according to the cognitive logic. A teaching form based on knowledge graphs can dynamically generate course materials, show how knowledge is connected, and adjust the cognitive load of learners according to the structure of the graph. Course reconstruction based on knowledge graphs can organise the knowledge in the system more rationally, improve the adaptability of courses to changes in the curriculum, and provide systematic support for differentiated instruction.*

Keywords: *Knowledge Graph, Communication Electronic Circuit, Course Content Reconstruction, Knowledge Modeling, Semantic Association, Cognitive Navigation*

Introduction

The Communication Electronic Circuit course has laid the foundation for all other knowledge of devices and systems, and it is also a prerequisite for other basic circuits and the communication major. The required functions of the course are amplifiers and mixers, and there are many logical dependencies among the knowledge modules. The current course has a linear division of chapters, and all the knowledge in them is relatively independent; thus, it is difficult for learners to form an all-encompassing system view of the subject. At the same time, there have been rapid developments in the technology of communication electronics, but there is a time lag in the development of engineering technology and its updating of course content; thus, course reform needs to be both systematic and flexible. Semantic Networks are a kind of knowledge representation that shows information in terms of subjects and relations. Build a course knowledge graph to organise the knowledge in a new way, explore graph-driven development of teaching forms, and improve the effectiveness of course teaching according to the development needs of the discipline.

1. Construction Mechanism of the Knowledge Graph for the Communication Electronic Circuit Course

1.1 Modeling and Hierarchical Structure of the Subject Knowledge Ontology

The knowledge system of the Communication Electronic Circuit course has many levels of content, such as low frequency and high frequency, unit circuits, system integration, etc. Given that it is very complicated, the foundation for organising knowledge needs to be a strong ontology. The construction of the subject knowledge ontology begins by extracting and defining the basic concepts of the course, such as general features of components, principles of amplifier circuit design, oscillation and feedback theory, modulation and demodulation techniques, etc. Formally defining the connotation and extension of these concepts can help us specify the class relationships and attribute characteristics of the concepts, and thus build a computable set of knowledge units.

According to the definition of the concept, a hierarchy for the knowledge system will be introduced. According to the internal logic of the Communication Electronic Circuits course, the knowledge points are divided into three successive stages: the foundation theory stage, the functional circuit stage, and the system application stage. The foundation of the theory layer is semiconductor physics and signal analysis tools; the functional circuit layer has many kinds of amplification, oscillation, mixing and filtering circuit topologies; and the system application layer is the architecture design of receivers and transmitters. The division of hierarchy above shows the progress of knowledge from abstract ideas to practical application, and a structural basis has been provided for the following mining of knowledge associations and organisation of resources[1].

1.2 Mining and Representation of Semantic Associations Among Knowledge Units

There are many logical dependencies among the knowledge points in the Communication Electronic Circuit course, and a simple list of concepts cannot show the structure of disciplinary knowledge. Systematic mining of semantic associations should be carried out by examining the causal, supportive, similarity-based and derivational relations among knowledge points. For instance, the Design of an oscillator circuit is based on the theory of feedback control, and the performance analysis of a mixer employs the basic ideas of nonlinear circuits. By organising the above links, a multi-dimensional relationship network of knowledge points is formed, and thus the knowledge graph can store facts and also reflect disciplinary logic.

Based on relationship mining, the above associations can be represented in the form of a semantic network. Many kinds of association edges have been set up; for example, the "prerequisite-successor" relation is used to show the order of learning, the "parameter-function" relation is employed to connect circuit specifications and implementation methods, and the "principle-application" relation is used to link theoretical knowledge with engineering practice. Set a specific semantic type and weight attribute for the association edge to allow for more detailed reasoning and navigation in the knowledge graph. The first is to organise the scattered points of knowledge into a system of knowledge and then revise the contents of the course accordingly.

1.3 Fusion and Representation Methods for Multi-Source Heterogeneous Knowledge Resources

There are many places to get teaching materials for the Communication Electronic Circuits course; for example, there is the theoretical description in the textbook, the topological structure in circuit atlases, waveform data from simulation software, and measured results from experimental platforms. To integrate all kinds of resources in a single knowledge graph, we need to solve the problem of alignment for different levels of granularity and indexing of attributes. Natural language processing technology is used to extract the general ideas and relationships in the text data. Recognition of images is employed to read the graphic materials and obtain circuit connections and component information. Quantify the attributes of the simulation data, such as frequency response and gain curves, and create indexable resource nodes.

The first step in integrating many kinds of resources is to create a map that links them to knowledge units. All the teaching materials have been annotated with their main ideas and related information, and some links have also been added between resource nodes and concept nodes. For example, a simulation file based on the idea of amplitude modulation can be linked not only to the concept of the "amplitude modulation principle" but also to related units such as the "multiplier circuit" and "envelope detection". Many-to-many mappings can be employed in the knowledge graph to connect abstract theories with real life, and students will be able to move freely between conceptual understanding and engineering application to strengthen all-round ability in the course.

2. Reconstruction Path of the Course Knowledge System Based on Knowledge Graphs

2.1 Modular Reorganisation and Topological Optimisation of the Knowledge System

Traditionally, the Communication Electronic Circuit course has been taught in a linear manner, and the content of the chapters generally includes semiconductor devices and basic amplifier circuits, high-frequency oscillation and modulation techniques, etc. Although the above arrangement meets the demands for knowledge organisation at this time, some of the original links among the knowledge items have also been broken. A knowledge graph can be used to break the linearity of the introduction.

Based on the concept association degrees and functional clustering features of the graph, the content of the course can be divided into several knowledge modules that have internal logical cohesion. Nonlinear Circuits, Mixers and Frequency multipliers for frequency conversion are in the module "Frequency transformation technology", and Resonant circuits, Filters and frequency-selective amplifiers for signal selection are organised in the module "Frequency-selective network and filtering". Modularity is based on the internal logical connections of knowledge, so the course structure is closer to the systematic nature of the subject itself[2].

Modularity is employed to improve the organisation of knowledge in a topological manner. Based on the strength and type of semantic association in the graph, we can find the core nodes and important paths of the knowledge network. For hub knowledge points that are at the intersection of several paths, such as the principle of negative feedback and the concept of impedance matching, prerequisites and bridging statuses have been set in the course arrangement to make them bridges among the various modules. Knowledge points with few associations or that are strongly independent will be added to the modules as additional study materials in that area. Topological optimisation has changed the structure of the knowledge system in the course from linear to hierarchical and networked organic; although it is still possible to learn them sequentially, concepts in different chapters can now be cross-referenced to build a more systematic disciplinary cognitive framework for students.

2.2 Fusion and Integration Design of Cross-chapter Knowledge Nodes

There are many knowledge nodes in the Communication Electronic Circuit course that span the boundaries of the traditional chapters, and these nodes are often the keys to understanding complex circuit systems. For example, the Design of an Oscillator has many points of knowledge distributed in different chapters, such as the basic idea of transistor amplification, feedback control theory, properties of frequency-selective networks, and analysis of frequency stability. In the old course structure, these parts are taught separately, and students cannot combine them to get the whole picture of oscillator design. Based on the knowledge graph, the fused Design will connect these dispersed knowledge nodes and form clusters of knowledge around the main problems.

To achieve the fused Design, we need to show the cross-hierarchical associations in the graph explicitly. Mark the multi-hop paths from the "oscillator" node to nodes such as "amplifier circuit", "feedback criterion" and "resonant circuit" in the graph to show the position and reachability of the oscillator in the knowledge network. The organisation of the course content can be based on the logical dependence of these related nodes, and topical knowledge clusters can be formed around functional circuits, such as oscillators, amplifiers and mixers. Based on the association paths in the graph, learners can learn how knowledge from different chapters is organised in the same cognitive system to achieve specific circuit functions. Generally speaking, the Design will connect all the knowledge points to form functional knowledge chains, strengthen the link between theory and practice in engineering, and change the content of the course from a list of knowledge items to a presentation of a knowledge network.

2.3 Planning of Knowledge Navigation Paths Based on Cognitive Logic

The learner's thinking is in the process of moving from concrete to abstract and from simple to complex. Although the multi-dimensional association network of a knowledge graph can show the whole structure of knowledge in a certain area, it is too complex for people to understand directly. Therefore, the path of knowledge navigation should be designed according to the cognitive logic of the graph, and learners need to be given clear direction on the order of learning. Planning of Navigation Paths is based on the dependency relationships in the knowledge graph, and it finds the necessary conditions and extensions for each knowledge node. For knowledge points with an obvious dependency relationship, such as the "amplitude modulation principle", it needs to be learned after the "multiplier circuit", and the "phase-locked loop" should be developed after the "feedback control"; thus, path planning ensures that the learning sequence is in line with the internal logic of the knowledge.

Plan the Navigation Path according to different learning objectives and various circumstances of the students. There are many choices for the different stages of learning, and various demands are placed on the task shown in the graph. Generally speaking, one can introduce the general ideas first and then, by going through the backbone nodes of the graph one by one, learn some necessary skills. The Extended Path will show some other circuit shapes or new technologies in the outer ring of the graph. The Paths are connected to each other by common nodes in the graph, and learners can freely switch between the main path and the side paths according to their own learning progress. A Multi-path Navigation based on a graph can be organised reasonably to allow learners to study at their own pace according to different learning requirements and in line with how people learn[3].

3. The Evolution of Course Teaching Forms Driven by Knowledge Graphs

3.1 The Dynamic Generation Mode of Course Content Supported by the Knowledge Graph

The field of Communication Electronic Circuits is developing at a high speed, and with the continuous appearance of new circuit topologies, integrated devices, modulation techniques, etc., the demands for the timeliness of course content have been rising accordingly. The update cycle of the traditional textbooks is relatively long, so they cannot keep up with the new developments in this field at present, and there has been a lag in the development of course content and changes in engineering technology. Add a knowledge graph to help generate course materials dynamically and provide some technical support. The graph has good scalability, and new knowledge nodes can be added one by one by defining their attributes and relationships with the existing nodes. When a new technology, such as the widely used software-defined radio architecture or a new kind of power amplifier topology, enters the field, it can be added to the corresponding position in the knowledge graph, and its logical connections with basic concepts and functional circuits need to be defined. Therefore, not only will the new knowledge be added, but the association paths will also be updated automatically to ensure that the new nodes are in harmony with the existing knowledge system and the course content is always in line with the development of the discipline.

Dynamic Generation Mode based on the Knowledge Graph can be employed to modify the organisation mode of course content. Knowledge associations in the graph can be used as the basis for content screening and combination, so the generation of course materials will change from fixed arrangement to on-demand collection. At different times in the course, based on the teaching themes, corresponding subgraphs can be extracted from the graph to form micro-course units focused on specific topics. For example, in the teaching of the structure of a modern receiver, the subgraph consisting of nodes such as the mixer, local oscillator, filter and analogue-to-digital converter can be extracted from the graph and connected with relevant theoretical explanations and simulation cases. Given the changes in the development of the subject, the graph-based content generation mode can be modified, and new materials are added reasonably to the existing system and organised logically at the same time. Subgraphs of different teaching themes can be automatically generated according to the association strength and logical hierarchy in the graph, avoiding the rigidity and lag of course content and forming a dynamic mechanism for the evolution of course content that is in line with the development of the discipline[4].

3.2 Design of Knowledge Visualization Presentation and Multidimensional Interaction Mechanism

The Communication Electronic Circuit course has a large number of abstract concepts and complex signal flows, and its knowledge representation is in the form of space and time. Traditional texts and static diagrams have some deficiencies in presenting such knowledge, and it is difficult for learners to form a dynamic imagination of the signal transformation process and circuit behaviour in static media. Visualization technology for knowledge graphs is now employed to present the knowledge in a different manner. Show the knowledge network of the course in the form of a node-link diagram so that learners can gain an intuitive understanding of the relative positions and association densities of all the knowledge units, thus forming a spatial cognition of the whole structure of the discipline. For concepts involving changes in parameters, such as oscillation conditions and frequency response, dynamic adjustment of visualisation elements can be used to show how the trend of circuit behaviour is affected by changes in component parameters; thus, abstract processes like frequency drift and gain variation can be given concrete visual forms, and implicit signal relationships can be turned into explicit visual attributes.

All kinds of interaction modes will be added to expand the network for students to learn about. In the visualisation window of the graph, learners can click on a node to expand the related knowledge information, trace the derivation paths or engineering mapping relationships among concepts, and thus perform non-linear exploration of the knowledge network. Composite Structures, such as multistage amplifier circuits or phase-locked loops, can be analysed by switching between the whole block diagram and the details of the unit circuits, and cognitive links are formed at different levels of abstraction. Trajectory data of interaction can be used to know how learners are exploring the knowledge network, which parts interest them more, and which are difficult for them; this data can then be used to optimise the navigation and organisation of content. Visualization and interaction are combined in the Design to turn the knowledge graph, an organised type of data, into a thinking tool; thus, students can explore and build a general sense of the disciplinary system of Communication Electronic Circuits actively, moving from a passive mode of reception to that of active construction[5].

3.3 Graph-Based Regulation Strategy for Learners' Cognitive Load

Although the complex network structure of the knowledge graph shows all the internal connections of the discipline, displaying it directly may exceed the information processing capacity of learners and cause a high cognitive load. A different display mode for the graph will be used to help the students learn better. Graphs have the attribute of controllable information density, so at different stages of students' knowledge and learning, various levels of detail can be displayed in the graphs. When learners first learn about a new concept, only the main nodes and basic connections are shown, and specific attributes and link details are left out; thus, they can focus on building a foundation without being overwhelmed by too much information. We will gradually add more supporting knowledge and links to the main ideas we have just learned so that you can see the whole picture. Thus, the density growth of the knowledge network is in line with the development of students' cognitive abilities, and a gradual path of cognitive progress has been formed.

Build a graph and, according to the graph regulation, change the direction of the learning path. Based on the graphs of learner navigation and stay-time, it can be seen how well students have grasped some parts of the knowledge and what kinds of learning methods they prefer. Nodes with short dwell times or frequent skips are given more visual weight in the graph to show that these important connection points in the knowledge network need to be paid more attention to. Nodes that have been visited many times are given a lower weight, and learners are motivated to explore the surrounding area so as not to get stuck in a single node. In the analysis of complex circuits, the graph can automatically highlight a small number of knowledge points that are relevant to the current task and filter out the rest; thus, it reduces the external cognitive load on students and enables them to concentrate more on solving the main problems. Graph-based regulation of cognitive load is a type of control that moves from passive observation of results to active guidance of the process; it offers an organised way to carry out differentiated instruction and helps learners at all stages of their studies meet their cognitive demands with the help of graphs.

Conclusion

The problem of knowledge organisation in the Communication Electronic Circuits course is the subject of this study, and it investigates how to reconstruct the course content based on a knowledge graph. At the level of the construction mechanism, the hierarchical model of the subject knowledge ontology defines the class relationships and hierarchical structure of the knowledge units; mining and representation of semantic associations build a multi-dimensional relationship network among the knowledge points, and fusion mapping of multi-source heterogeneous resources is used to connect abstract concepts with engineering examples. According to the knowledge association information in the graph at the level of the reconstruction path, modular organisation and topological optimisation are carried out to change the structure of the course from a linear sequence to a network; fusion design of cross-chapter knowledge nodes is used to create function-oriented knowledge aggregation units, and planning of multi-path navigation sequences according to cognitive laws provides structured support for differentiated learning. At the level of teaching form, a graph can dynamically generate course content and adjust the course in light of changes in the subject; it is a knowledge visualisation and multi-dimensional interaction tool that makes learning materials more accessible, and based on a graph, a regulation strategy for cognitive load can be employed to dynamically adjust the amount of information according to students' cognitive levels. Organised structure of knowledge for the Communication Electronic Circuits course is presented in this paper. Later, one will learn about the automatic construction and updating mechanism of graphs, graph-based learning behaviour analysis, and the application of graph technology in other professional courses.

Fund Projects

The Ministry of Education’s Industry-University Cooperation Collaborative Education Project: Research on the Dual-Driven Training Mechanism for Dual-Qualified Teachers in Communication Electronic Circuit Courses by Digital Empowerment and Enterprise Practice, Project No. 250903494191127.

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