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論　文　名	「Study on Distributed e-Learning Management Systems（分散型 e-ラーニング管理システムに関する研究）」
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論　文　要　旨

Internet technologies are currently being increasingly employed in the field of education such as e-Learning and distance learning systems. e-Learning systems generally have three components of 1) a user interface that is customized for target users in an organization (students, teachers, and administrators), 2) a general software component, called a common learning engine for learning and teaching, which is independent of the user interface and learning content, and 3) a database for domain oriented learning content and learning logs. Of these, the common learning engine has reduced the load in developing individualized e-Learning systems for specific schools or organizations.

Although the number of organizations in Thailand that implemented e-Learning systems was around 40,000 in 2009, it exceeded 60,000 in 2012, and it is still increasing. Therefore, each e-Learning system has its own learning content. Teachers should prepare learning content by themselves for their students with their limited resources even if excellent content may exist in other e-Learning systems. Such tasks in preparing learning content are time-consuming and costly. It is also well known that some teachers cannot develop their own learning contents because they have deficient IT knowledge. There is no chance, on the other hand, for students in e-Learning systems to obtain learning content from other e-Learning systems even if it is openly disclosed, which is wasteful. The more learning

content students use, the smarter they become.

Sharing of learning content by schools and organizations has become more significant and necessary under such circumstances. This should be transparent among e-Learning systems where transparency means that users do not need to be conscious of the real location of learning content. Users do not generally need to share learning content in the first stage. Once they cannot help using e-Learning systems, the requirement to share learning content becomes clear. Learning logs that can be shared among schools and organizations should suggest future learning directions in the final stage. There should be an account on stepwise growth for sharing learning content.

The main purpose of this research is to devise a new mechanism by combining existing and prospective LMSs on the Internet and to share their learning content among users in a richer learning environment. This research proposes a new concept, called a Distributed Learning Management System (DLMS). This thesis clarifies the reasons DLMS is required. Then, a practical example is presented in the thesis for the proposed DLMS by science teachers. It also explains how DLMS was designed and how the prototype was evaluated that compared the evaluation of DLMS for SOAP base and REST base implementation. In addition, it proposes the future possibility of DLMS based growth of capabilities in trajectory mining.

Chapter 2 provides four alternatives for sharing learning content in e-Learning systems (why DLMS is required): (1) a method of replicating shared content, (2) a method of centralizing shared content, (3) a method of remotely logging in to shared content (multi-login), and (4) a method of sharing distributed content. This chapter discusses the potential problems with these alternatives with simple illustrations that present these system structures and data flows. This chapter also clarifies the features embedded in the alternatives by comparing the viewpoints of students, teachers, and administrators. This chapter explains an evaluation of the performance of DLMS and LMS for ten students and seven LMS systems on the 250 Mbps Internet. Chapter 2 also compares alternatives of sharing learning content which provided both qualitative and quantitative evaluation. The proposed distributed approach was found to be preferable in the final stage as a result of the comparison.

Chapter 3 focuses on a DLMS application (how to use DLMS). The main purpose of the application was to support science teachers to prepare for their classes. The teachers in

this application should be regarded as students within the context of the e-Learning system. Then, the chapter introduces the concepts and principles underlying shared digital content based on a working DLMS. The proposed framework is divided into three parts: The first part describes the background for digital content sharing by science teachers. The second part explains the designs of the evolutionary process for contents sharing based on Capability Maturity Model Integration (CMMI), which includes five stages. The final part illustrates a scenario on how the proposed framework works. Content constructors such as science teachers are expected to save a great deal of time in preparing digital content that will be presented to their students with this framework.

Chapter 4 explains the designs for the data flows for the Distributed e-Learning Management System based on a standard protocol (how to implement DLMS). First, it reviews the features of learning content that are different from those of simple HTML pages. Their sizes are generally too large to use the Simple Object Access Protocol (SOAP) for communication between e-Learning systems. The SOAP and Representational State Transfer (REST)ful Web services were compared, and why the latter is superior to the former for DLMS is clarified. A data flow diagram and class diagram are specified that follow the conceptual design. This chapter explains an evaluation of the performance of DLMS by implementing the prototype base on SOAP-base and REST-base implementation.

Chapter 5 suggests future possibilities by introducing capabilities for trajectory mining. It discusses ways to support improved individualized learning processes based on trajectory mining. Trajectory mining is a type of mining for extracting dependency knowledge from time-series data. The system is expected to provide students with better learning support through the use of this technology. This chapter consists of four parts. The first part introduces data mining and related works. The second part reviews what capabilities trajectory mining has for learning logs. The third part introduces the basic idea behind the proposal. This part reviews the Spiral Enhancement capability support system (SPICE) and CMMI used for analysis. The third part explains the design of a questionnaire for a sample group (TNI student capabilities). The final part proposes the possibility of learning log under DLMS and an algorithm for message generation. In addition, this part proposes support for planning in the growth of capabilities for trajectory mining for student recommendations.

Chapter 6 finally concludes this thesis by summarizing the previous chapters.

審 査 結 果 の 要 旨

本論文は，学習教材の組織間での共有方式に関するもので，特に分散型のアーキテクチャで構築することを主張したものである．最初に分散型アーキテクチャとは何かを他の手法と比較することにより明らかにし，次にどのような状況で提案アーキテクチャが利用できるかを述べている．さらに，分散型アーキテクチャを標準のプロトコルを用いて実装する方法を詳細に述べ，最後に今後の可能性について言及しており，次の成果をあげている．

（１）e-Learning Management System の構造を，組織ごとにカスタマイズしたユーザインタフェース，組織の具備する教材と汎用的な学習エンジンからなるとした上で，組織間で教材を共有する方法の代替案を４通り示した．レプリケーション方式，中央集中方式，リモートログイン方式，分散方式の定性的・定量的特質を分析し，今後は分散方式が重要になることを示した．

（２）学校の理科教育に電子的な教材を利用する状況において，先駆的な利用者と追随的な利用者を分けて，習熟とともにどのように教材を共有するかの分析を行った．その結果として，最終的には分散型のアーキテクチャの e-Learning Management System が好適であることを示した．

（３）分散型のアーキテクチャの標準のプロトコルで実装する方式として SOAP プロトコルを利用する方法と RESTful プロトコルを利用する方法を比較し，後者の優位性を導いた．ＵＭＬ言語を用いて実装方法を詳細に論じたのち，簡単なプロトタイプを実装し，その性能評価を行っている．

（４）学習履歴の透過的な共有を分散型アーキテクチャで行う将来的な可能性について言及し，学習履歴から得られた知見をメッセージとして生成したり，将来の学習計画をメッセージとして生成したりする方法を示した．さらに申請者の所属する大学の学生のデータを用いて適用方法を示した．

以上の研究成果は，知能情報工学分野における分散型 e-Learning 管理システムに対する新しいアプローチを示唆しており，関連分野の発展に貢献したと考えられる．また，申請者が自立して研究活動を行うに必要な能力と学識を有することを証したものである．本委員会は，本論文の審査および最終試験の結果から，申請者に対して博士（工学）の学位を授与することを適当と認める．