A TOOL FOR MANAGING DOMAIN KNOWLEDGE IN INTELLIGENT TUTORING SYSTEMS

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Abstract: Domain knowledge (DK) is a basic part of an intelligent tutoring system (ITS). DK usually includes information about the concepts the ITS is dealing with and the teaching material itself, which can be considered as a set of learning objects (LOs). LOs are described by a data set called learning object metadata. Concepts are usually organized in a network, called a concept network or map. Each concept is associated with a number of LOs. In this paper, we present a tool for managing both types of information in DM: creating and editing (a) a concept network and (b) learning object metadata. Additionally, the tool can produce corresponding XML descriptions for each learning object metadata. Existing tools do not offer all the above capabilities.

1 INTRODUCTION

Recent developments in computer-based educational systems gave rise to a new generation of them encompassing intelligence in order to increase their effectiveness, called intelligent educational systems. Intelligent Tutoring Systems (ITSs) constitute a popular type of intelligent educational systems. ITSs take into account the user's knowledge level and skills and adapt presentation of the teaching material to the needs and abilities of individual users. This is achieved by using Artificial Intelligence techniques to represent pedagogical decisions as well as domain knowledge and information regarding each student. ITSs were usually developed as stand-alone systems. However, the emergence of the WWW gave rise to Web-based ITSs (Brusilovski, 1999; Hatzilygeroudis, 2004).

The structure of an ITS is illustrated in Figure 1. An ITS consists of three main modules: (a) the domain knowledge, which contains the teaching content and meta-information about the subject to be taught, (b) the user model, which records information concerning the user, and (c) the pedagogical model, which encompasses knowledge regarding various pedagogical decisions.

In the domain knowledge, the teaching material must be structured in such a way that can be easily recognized and used by the pedagogical unit, in order to adapt teaching to user's needs. A quite helpful way is to distinguish between the teaching material itself and its meta-information, typically called its metadata. The teaching material itself usually consists of learning objects (LOs), which are autonomous, self-contained digital entities (e.g. web pages) used to support learning (Wikipedia, 2008). To be able to manage domain knowledge in an ITS, we need a tool that will be able to manage LOs metadata and real teaching material too. However, apart from those, domain knowledge also contains information about the concepts the system is concerned with. Although there are a number of tools dealing with management of metadata for LOs, most of them are not suitable for dealing with concepts. On the other hand, although there are tools dealing with concepts, they are not able to relate them with LOs.

In this paper, we present a tool that is able to deal with both LOs and their metadata description as well as with concepts and their relations. Also, it helps tutors in preparing lessons. Description of LOs metadata is based on the IEEE LOM standard (IEEE LTSC, 2002; Holzinger et all, 2001).

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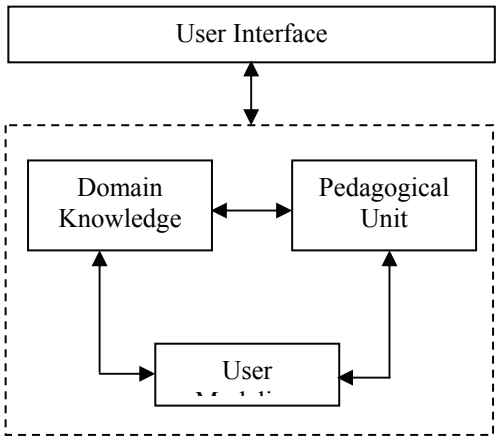

Figure 1: The Basic Structure of an Intelligent Tutoring System.

The paper is structured as follows. Section 2 presents the structure of domain knowledge in an ITS and its requirements of managing it. Section 3 deals with the functional characteristics of the introduced tool, while Section 4 presents some design and implementation issues. Section 5 presents related work and shows the inadequacies of existing tools. Finally, Section 5 concludes the paper.

2 DOMAIN KNOWLEDGE

The motivation for creating such a tool was the need for managing the domain knowledge of a certain ITS. To be able to manage its domain knowledge, it has been structured as displayed in Figure 2. So, it consists of three components: knowledge concepts, course units and meta-description.

The knowledge concepts are elementary pieces of information of the specific domain. Every concept has a number of general characteristics such as the name, the difficulty level, the detail level, the prerequisite knowledge, etc. Moreover, a concept has relations with the other concepts which mainly show the prerequisite concepts that contain the perquisite knowledge for that concept. For example, in teaching logic in an Artificial Intelligence course, 'logic syntax' and 'logic semantics' could be two concepts. 'logic syntax' could have as prerequisites the concepts 'constant', 'variable', function' etc. However, there may be other types of relations, like "generalizes", "specializes", "part-of" etc. For example, 'left-hand expression' may be "part-of" 'implies expression'. The concepts and their links form a network (see Figure 3), which is a semantic network that represents the pedagogical structure of the teaching subject.

The teaching material consists of two parts: (a) the course units and (b) the meta-description. The course units mainly are in the form of web pages and are equivalent to LOs. Each course unit may contain a variety of data types (e.g. text, images, animations etc).

Course units are used in composing lessons. Each course unit is related to a concept and through the concept network, that has been created, the system chooses the next course unit (web page) to be presented to the user. A course unit can be of a theory, an example or an exercise type. Examples help the student to understand in a better way the theory. Exercises are based on the examples and are used to evaluate the knowledge level of the user. This information is used to update the model of the user.

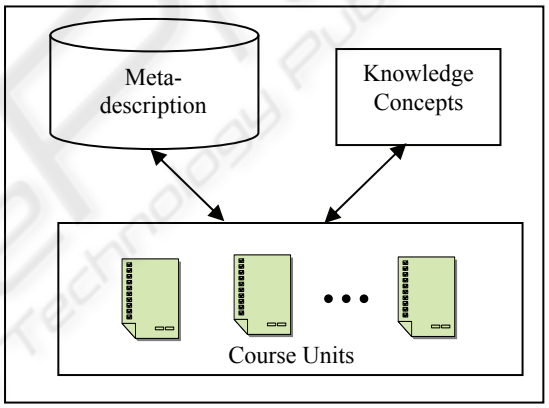

Figure 2: The Structure of Domain Knowledge.

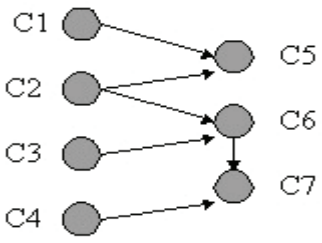

Figure 3: A Concept Network.

The knowledge domain also contains meta-descriptions of the course units and their main attributes. Such attributes are mainly its difficulty level, its pedagogical type (theory, example, exercise), its representation type (text, image, animation), its detail level, etc. Those meta-

descriptions of the course units are based on the IEEE LOM standard schema (IEEE LTSC, 2002).

3 A TOOL FOR MANAGING DOMAIN KNOWLEDGE

We created a tool for managing the domain knowledge of an ITS based on the above. So, using the tool one can create the concept network of a domain, using a variety of relation links, which him/herself can define. Also, can create, store, view and edit the metadata for the LOs (i.e. course units) in XML format.

3.1 Concept Map

The tool provides facilities for easily creating a map (network) of the concepts involved in the domain.

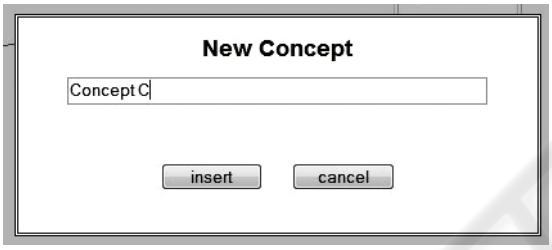

Figure 5: New Concept Creation.

To create a new concept, one can click on the tool workspace and choose "Add concept". Then the interactive form of Fig. 5 appears where he/she can define the name of the new concept.

To create a relation between two concepts, one should click on the icon, lying at the right-hand side of a concept (Fig. 7), and then on the related concept. The interactive form of Figure 6 appears where he/she can choose a relation type from a list of existing ones or create a new type of relation.

Figure 7 shows two concepts connected with a "requires" relation. At each concept one can see, at the first glance, the name of the concept and its relations with other concepts. Also, when the mouse is over a concept one can see more icons that perform certain functions. The icon calls the renaming function; the icon calls the function that deletes a relation; and the icon deletes the selected concept.

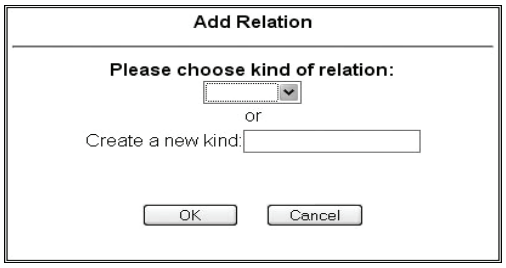

Figure 6: Form for adding a relation.

The user can insert concepts at any position of the concept map, drag the concepts across the map in order to organize them, create new relations and connect them. In Figure 8, a concept network, where concepts are connected with various types of relations, is presented.

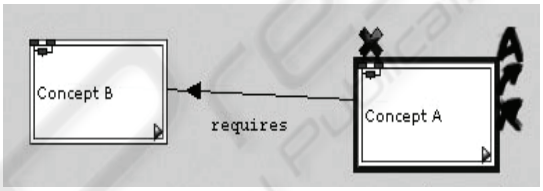

Figure 7: Concept Map Creation.

For the convenience of the users, there is a search bar, which we can give in any keyword related to concepts or to the metadata of the learning objects. The result is to center the concept map to the selected concept and highlight it.

3.2 Managing Learning Objects

The learning objects (course units) attached (i.e. related) to each concept can be displayed by double clicking on the corresponding concept (see Fig. 9). We can add/create a learning object, by clicking on the "Add Learning object" link or delete any of the existing ones (not shown in Fig. 9).

Having displayed the learning objects, we can do two other things:

(a) Display and edit its metadata, by clicking on the "Edit Metadata" link of a learning object (see Figure 9). Its metadata appears in a structured way (see Figure 10) so that can be easily read and edited (i.e. modified/deleted), using the corresponding link in each metadata category. The structure of metadata follows the IEEE LOM standard. On this set of metadata there is the 'Relation' category, which however is not the same as the 'relation' between concepts. It specifies relationships between the learning objects (course units).

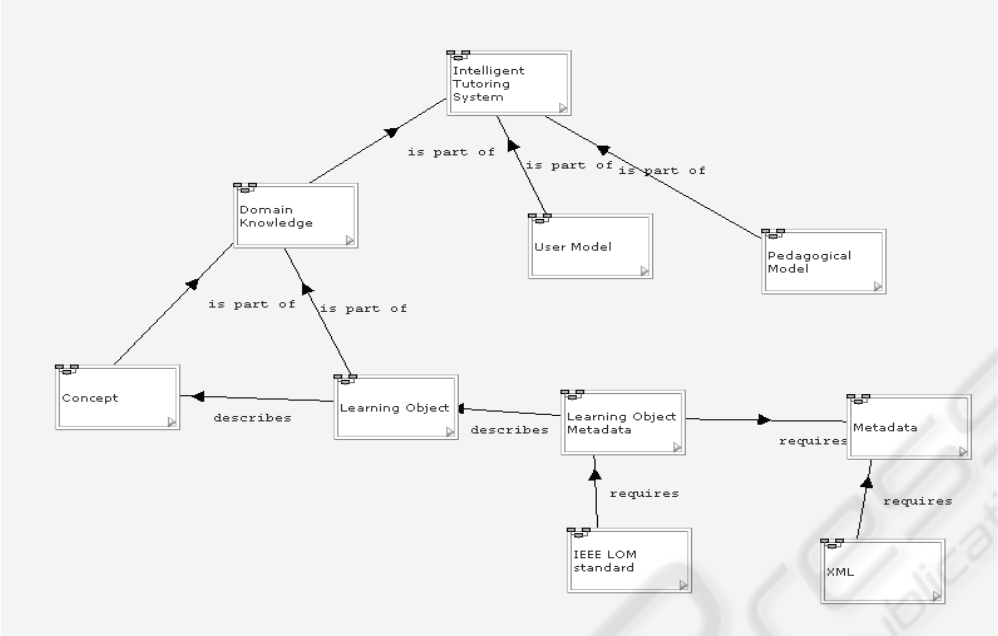

Figure 8: A Concept Map (Network).

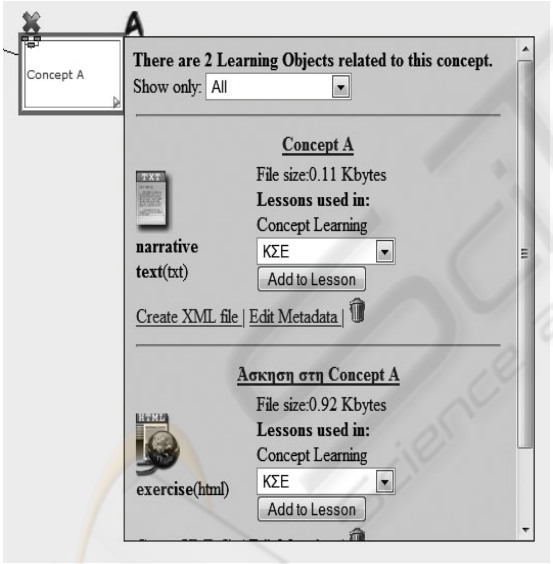

Figure 9: Displaying Learning Objects.

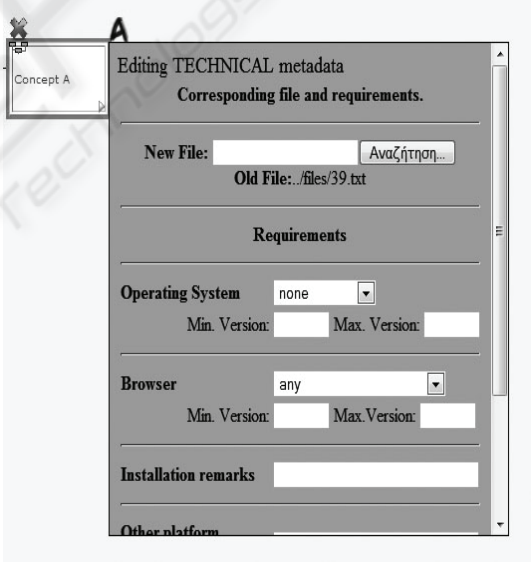

Figure 10: Displaying and Editing Metadata of a Learning Object.

(b) Create an XML file representing the object's metadata. The information that we have specified in the concept metadata is stored in our database as well as in XML files for future use. These XML files can be accessed by other elements of any other system that has access to our file system, which through that can decide on the selection of the concepts that will use in a tutoring session.

Therefore, we have included access to these files through links of our system. To see the XML file of a LO we should just click on the "Create XML file" link of the LO (Fig. 9). The XML file is then dynamically created (Fig. 11).

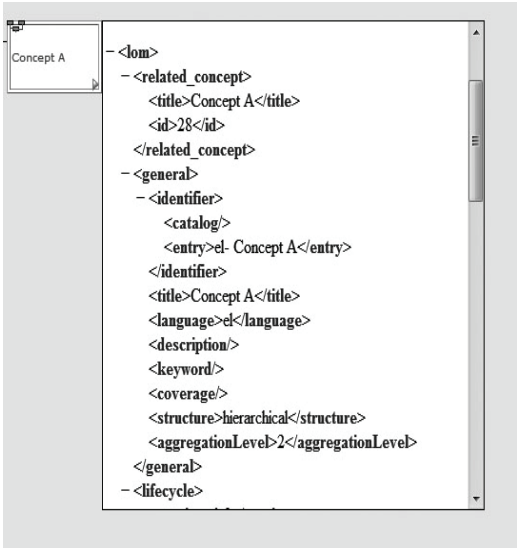

Figure 11: The XML file of a Learning Object.

4 SYSTEM DESIGN AND IMPLEMEMNTATION

The heart of the system is the relational database, which is designed to store all vital information concerning the concept description and connections, the LOs metadata as well user related data. The database is organized in 17 tables, apart from the one related to 'learning object' (see Fig. 12), 11 for metadata, 5 for the concept map and 1 for user identification.

WAMP5 version 1.6.1, containing Apache 1.3., PHP5 and MySQL4, was used for the implementation of the system. MySQL is used for the database, whereas PHP for the rest of the system, like e.g. the creation of XML files. For the concept map drawing, javascript was used from the Open-JACOB Draw2D library and the scipt.aculo.us library. The queries to MySQL are made through AJAX technology that connects the index.html file with the php files.

5 RELATED WORK

We distinguish two categories of tools to compare with ours. There are a number of tools, which are used for the management of metadata in learning objects. In spite of their many features, none of them was satisfactory to be used with the ITS.

LOM Editor (LOM-Editor, 2001) developed by Darmstadt University of Technology -Germany, and written in Java, is a standalone desktop application which includes superior abilities for editing metadata, such as: Tabular presentation of metadata categories; vocabulary management; multiple-language values management; metadata template generation to avoid the necessity to repeatedly enter the same data in multiple fields. Some of the drawbacks of this metadata authoring tool include: No help or documentation; omission of specific details of LOM Model (e.g. multiple-language values support for metadata elements); some standards like vCard and ISO 8601 DateTime standard are not supported in the representation of the metadata elements; storage of the metadata record is done in a database and there is no export option for the XML document.

ALOHA II (ALOHA II, 2004) is a Java-based tool that is used for indexing, aggregating, sharing, multi-purposing, and re-purposing learning objects. It is created to meet the needs of indexers, educators and learners and includes versatile and powerful indexing tools and flexible searching of multiple educational object repositories. The software is based on the educational standards of IMS and SCORM. ALOMA II is not web-based and not based on the IEEE LOM standard.

Curriculum Online Tagging Tool (Curriculum Online Tagging Tool, 2008) which is designed to make the process of creating metadata and outputting as easy and intuitive as possible. A version of this tool is being developed to support UK LOM Core and aspects of CanCore. It enables creation and storage of details about the learning resources. It also allows adding those details to the Curriculum Online portal, so that teachers can find out about the learning resources. Once the details about a resource are added to the portal, the tagging tool can be used to update them at any time, or even remove them completely. This tool cannot create a network of resources, but just an unstructured repository of them.

Explor@-II (EXPLORA-II, 2008) is a software environment for the delivery of courses or distance learning events on the Internet. It allows creating a virtual training centre that delivers a set of courses on the Internet according to a variety of models and using a LO repository facilitating information access, production, follow-up and coaching of learners as well as training management. It is fully compatible with the IEEE LOM, Cancore and Normetic. Explor@-II is more an e-learning environment, not web-based, rather than a domain knowledge management tool.

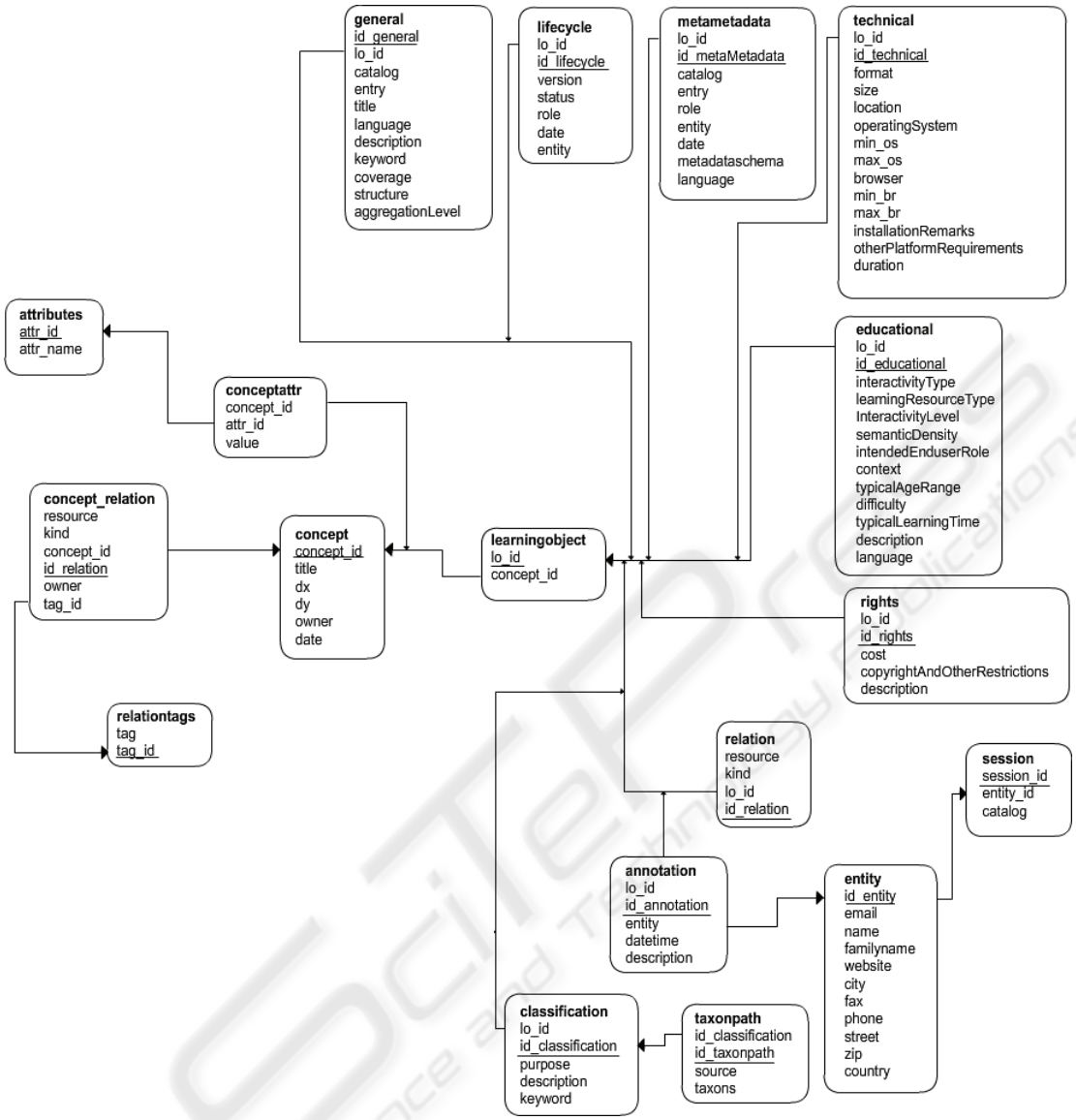

Figure 12: Database Relations Diagram.

The second category concerns tools that mainly deal with creating concepts and concept maps. Inspiration (Inspiration, 2008) uses a web as a basic graph structure, and repositions the initially entered concept in the middle of the screen. This tool does not enforce any particular graph structure, and the representation does not require linking phrases. The software allows the user to switch from graph to outline view and back. SMART Ideas (SMART Ideas, 2008) allows users to create multi-level Concept Maps to organize ideas, to link Concept Maps to files and Web sites, to switch between diagram and outline views, and to publish Concept Maps on the Web. LifeMap (LifeMap, 2008) is designed for free educational use. Group packages with support are available. LifeMap provides the capability to make Vee diagrams as described in (Novak and Gowin, 1984). IHMC CmapTools software kit (Cañas et al, 2003a) is to enable users to collaborate during Concept Map construction and to easily share and publish the resulting knowledge models. The software is based on a client-server architecture (Cañas et al, 2003b) that allows users to share and browse Concept Maps stored in CmapServers distributed throughout a network that covers the whole world. Luckie Concept Connector is a software suite currently in development at Michigan State University. This system allows

students to build Concept Maps online and to receive immediate feedback about their maps based on automatic scoring systems that are derived from scoring methods detailed in (Novak and Gowin, 1984). The Concept Mapping system is based upon a pre-defined set of concepts and linking phrases. The system is currently being used for online homework assignments.

6 CONCLUSIONS

In this paper, we present a tool that is suitable for managing the domain knowledge in an ITS. More specifically, the tool allows for creating, viewing, editing and deleting knowledge concepts, which are organized in a network (map). Concepts are connected between each other by a variety of relations (e.g. “requires”, “isa” etc), which can be user defined. Also, it allows associating concepts with corresponding learning objects, i.e. real teaching material. In addition, the user has the capability of adding to or modifying metadata (which complies with IEEE LOM data model) of each learning object associated with a concept and create XML files which he/she can view and edit in the process.

All the above are not offered by existing tools, as reported in Section 5. We’ve used the tool for the creation of the domain knowledge of an ITS teaching “Intelligent Tutoring Systems” (see Figure 8) and another one teaching “Aspects of Artificial Intelligence”. It has been really very helpful.

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