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Research and Implementation of Artificial Intelligence in Welding Process Design

Jianwei Yuan

College of Information Engineering, Shaanxi Polytechnic Institute, Xianyang 712000 China
yuan_cn@126.com

Aiming at the conflict between access and storage due to the continuous accumulation of knowledge storage in the field of artificial intelligence in welding, the author uses RDF (Resource Description Framework) to represent the technological knowledge of CO_2 gas shielded welding, designs and implements a knowledge base based on Web semantic and stores it in HDFS, which is used to solve the difficulties of mass data storage. By studying the mechanism and characteristics of spatter in CO_2 gas shielded welding, aiming at the common measures and means of reducing spatter, the author realizes the inference function based on welding process rules by using Jena framework and optimizes the craft realization, finally integrates the core functions into the Spring framework and adopts the HTML5-based interface design to enable a new welding process expert system across the Internet and mobile platform.

1. Introduction

With the continuous development and maturity of cloud computing, big data, IoT and other technologies, the modern manufacturing industry is accelerating the transition to digital and intelligent manufacturing. Welding is an important technology in modern industrial manufacturing and plays an important role in all aspects of the manufacturing industry. With the support of information technology, welding technique is also one of the areas where AI is tried and used early. Foreign research in this area started early with more research results, the welding materials selection system jointly developed the AWI and Colorado School of Mines is the earliest reported case, and thereafter Germany, Japan and other developed countries are conducting welding production information and intelligent research and experiment (Shen, 2016; Fu et al., 2006; Zhan et al., 2016; Meco et al., 2013). The main research directions in China are welding method selection, crack prediction, welding material selection, safety assessment, defect diagnosis, process selection, process design, metallographic identification and welding structure CAD, etc.
At present, in the process of digitalization of welding production, many researches and applications merely focus on the realization of basic functions or the simple data processing functions based on the query of traditional databases. At present, the main application of AI in the field of welding production is a variety of welding expert systems. Some welding expert systems often achieve knowledge acquisition and inference by means of limited data and knowledge. However, due to the bottleneck of knowledge organization and storage, the research and use of AI in welding production have been stagnant.

2. Research on CO_2 Gas Shielded Welding Process

2.1 Process characteristics

CO_2 gas shielded welding is a welding method with good processing property widely used in shipbuilding, automobile manufacturing, petrochemicals and construction machinery. CO_2 gas shielded welding is a low-hydrogen welding technique, compared with traditional welding techniques, during the welding process, its arc heat is concentrated and utilization rate is high, the energy consumption is small, the weld heat affected zone is narrow, the weld crack resistance is good and has reduction and rust resistance ability is strong, which is conducive to the realization of mechanization and automatic welding (Yu, 2003; Pang, 2012). In the general production environment, the CO_2 welding process adopts solid core thin wire (containing deoxidizer such as

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silicon and manganese combined deoxidization), equipped with constant wire-feed system and flat external characteristic power supply, DC reverse connection and short-circuiting transfer, which is suitable for welding thin carbon steel or thin alloy low alloy steel. With the continuous development of arc welding power and welding materials, CO_2 welding process is developing constantly and its application range is expanding. For example, the adoption of fine wire high current welding process (Xia, 1991) and CO_2 welding of medium-thick steel (Liang and Li, 2014). Therefore, with the changes in the production environment and production of products, CO_2 welding process also changes greatly.

2.2 Mechanism and control measures of spatter

The main problems that affect the quality of CO_2 gas shielded welding are spatter and porosity. The control these two factors is an important means to ensure welding quality. During the process of CO_2 gas shielded welding, the transition form of molten metal to molten pool is the main factor affecting spatter. In the free transition of droplets, large drop spatter is easily formed under the effect of droplet pressure, and there are more forms of spatter in short circuiting transition. The normal spatter rate of CO_2 gas shielded welding is 5% - 10%, and the normal welding can not be carried out when the spatter exceed 20% (Zhang et al., 2004), so it is necessary to control the spatter. Under normal circumstances, control can be done by adjusting equipment, process parameters, using mixed gas and flux cored wire and other means.

3. System Design

At present, a significant bottleneck of the development of welding expert system is that with the continuous expansion of knowledge data, the traditional database can not be efficiently managed and inferred, resulting in the system's knowledge can not continue to expand. In order to solve this problem, Hadoop cloud computing platform is used to provide technical support for mass storage and expansion of knowledge in the beginning of system design. Hadoop is a very mature open source cloud computing framework in the field of big data, which allows for the distributed processing of massive different types of data (structured, unstructured, etc.). MapReduce, a distributed data processing model, is the core technology of Hadoop. HDFS means Hadoop Distributed File System (Yang et al., 2014; Fan et al., 2013).

3.1 System structure

The author takes CO_2 gas shielded welding as the research object, conducts an in-depth study and analysis of its process, uses RDF (Resource Description Framework) for knowledge representation and builds knowledge base on HDFS, constructs a reasoner based on Jena RDF parsing tool, implements the Jena interface with the Spring Framework and provide data over the Web, uses HTML5 and Bootstrap framework for the front end to realize the cross-platform operation interface, and ultimately realizes the CO_2 gas protection welding process design expert system on the cloud computing platform, and the system structure is shown in Figure 1.

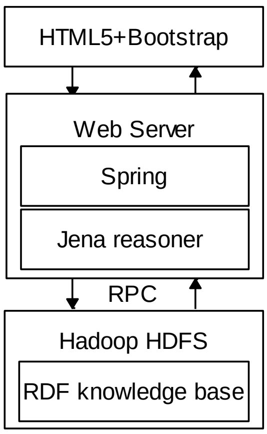

Figure 1: The System Structure Diagram

3.2 Knowledge base design

The optimization of knowledge base is the core of this system. Designing the knowledge base and rule base for CO_2 gas shielded welding and using RDF for knowledge representation is more conducive to the transmission in the network.

(1) RDF-based knowledge representation

Knowledge base used to store expert knowledge is an important part of the expert system. Traditional knowledge base design usually relies on knowledge stored in database. Although database has the advantages of convenient management and fast access, its structure is not suitable for all kinds of knowledge representation, so it can use the mixed representation of database and XML file. The design of knowledge base structure must be combined with the reasoner. This system uses Jena for knowledge parsing, so the RDF-based knowledge base is designed to match the requirements of Jena. Knowledge in the knowledge base can be divided into two categories: one is the fact – the initial facts inputted by users, the intermediate facts in inference procedure and the final conclusion – this part of knowledge is mainly various welding knowledge and national laws and regulations, standards and various experiences from welding experts, etc.; the other is the inference path that holds the sequence of rules activities (Liu et al., 2008; Tian et al., 2008). There are many ways to represent the factual process data in the knowledge base. The most common way to represent knowledge is first-order predicate. Predicate logic is a formal language and also the most precise language to express the rule of human thinking so far. It is very close to natural language and can be conveniently stored in and processed accurately by computers (Wan et al., 2008). RDF is a standardized framework for describing the information semantics of the Internet and realizing information reasoning on the Internet. It provides a model for representing the basic facts about resources. Using RDF to represent welding process knowledge can not only adapt the inference resources of the reasoner, but also facilitate the transmission on the Internet. The set of triplets of RDF essentially contains the subject, predicate and object. This representation of knowledge by using a set of triplets is similar to the representation of knowledge in the way of first-order predicate. The following is a representation of droplet transfer using RDF.

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:co2welding="http://www.xxx.com / co2welding #">
<rdf:Description
 rdf:about=" http://www.xxx.com /co2welding/ SpTr ">
 <co2welding:name> Spray transfer </co2welding:name>
</rdf:Description>
<rdf:Description
 rdf:about=" http://www.xxx.com /co2welding/ShCirTr">
 <co2welding:name> short circuiting transfer </co2welding:name>
 </rdf:Description>
……
</rdf:RDF>
```

The rule base mainly stores procedural knowledge – the basis of inference, which is used to solve problems and associates known knowledge with rules and other knowledge structures of other information that need to be deduced or speculated. The welding process qualification rules are abstracted according to the welding process assessment standards and coded to realize the rule base. The rule base contains mainly 3 types of rules: the first type is the parameters of the groove type and related welding process parameters derived from base metal type, thickness, type of joints, welding position and other initial information; the second type is rules of optimization of welding quality and welding production cost, which introduces some of the computer simulation data to further optimize the screening process, e.g. the simulation method used for stress analysis in literature 15 (Du and Wang, 2015); the third type is rules for the CO_2 gas shielded welding spatter improvement optimization.

For example: the base metal is 16MnR, the thickness is 12 and the welding current is 90-110, the rule of which can be represented by using the RDF simplified representation:

Rule 1: (? Base metal wk: is ? 16Mn) (? Welding current wk: is ? 110-210) (? Welding voltage wk: is ?13-22) -->(? Droplet transition wk: is ? Short-circuit transition)

(2) Knowledge base optimization

Although the process parameters of CO_2 gas shielded welding process are not complicated in many fusion welding processes, because of its obvious technological characteristics, it is necessary to develop actual production processes according to the technological characteristics when developing related processes. The spatter model base added to the system knowledge base is used to predict and analyze the spatter in the process, give correction parameters, and carry out further spatter analysis through the process modification until the process meets the requirements.

Factors that affect the spatter of the welding process are mainly the composition of the base metal and welding material, the control of welding process and the welding process parameters. Among them, the

content of C in the welding material and base metal has the most influence on the spatter. When the quality fraction of carbonium of the raw material exceeds 0.08%, the metal spatter particles increase obviously (Meng et al., 2012). Among many welding parameters, the influence of welding current on the spatter is the largest and the most complicated, which is not a simple linear relation (Liu et al., 2013). Based on the relation between the voltage and current generated by the spatter, the spatter analysis model base is designed with the rules of inference, which are revised by considering other theories, so that the process parameters deduced in the previous period can be analyzed and the possibility of spatter can be obtained.
(3) Knowledge base reading and writing
To facilitate mass storage of knowledge base, the knowledge base is stored in HDFS (Hadoop distributed file system). HDFS, a data storage system in Hadoop distributed computing, is developed based on the requirement of streaming data mode access and processing super large files. The system calls the metadata node through RPC on the Web Server and performs the actual data access on the DataNode. Using RPC programming is one of the most powerful and efficient ways to reliably communicate between the client and the physical server. In a distributed environment, the client and server run on different machines, the client side calls the process of running on the server side and sends the results back to the client.

3.3 Reasoner design

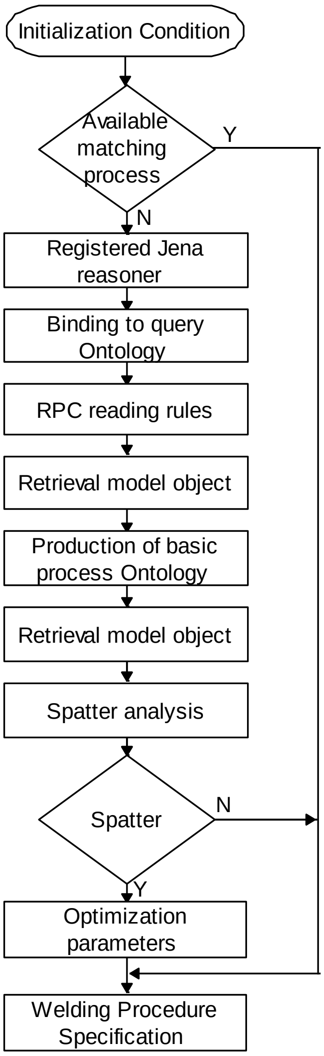

Figure 2: The Reasoner Architecture Based on Jena

Reasoner is one of the cores of the expert system. Based on the given initial conditions, it generates inference results according to the rules. Based on different knowledge representation, there will be different inference processes. After investigation and screening, the open source tool Jena developed by HP laboratory is adopted to realize online parsing and reasoning based on the JavaWeb framework under the premise of ensuring its good inference mechanism. Jena is a Java framework for building semantic web applications, which provides interface methods for manipulating RDF, RDFS, and OWL, as well as rules-based reasoner programming environments and can dynamically output some processing results for traditional data access and inference (Liu et al., 2006; Carroll et al., 2004; He et al., 2013).

The inference subsystem in Jena is one of the basic core systems. It provides a rule-based reasoner that, in addition to its general inference capabilities, provides inference based on custom rules. The Jena framework mainly reads and writes RDF, OWL, etc. in the form of RDF / XML and a set of triplets, and provides the storing of ontology data in the OWL file or the relational database, and in addition to the above functions, implements the SPARQL query language or the RDQL with the support of the ARQ query engine provided by it. Jena implements access inference mechanism through ModelFactory. First of all, the reasoner register, according to the knowledge in the welding process knowledge base based on RDF, uses the rules in the rule base to create a reasoner; then the reasoner and ontology to query and inference are bound together to obtain the model object (InfGraph) for retrieval. Finally, the established model object is operated and processed by means of Ontology API and Model API. Based on the concept inference, information retrieval based on semantic is completed to get the desired results (Tan et al., 2009). The CO_2 gas shielded welding inference process based on Jena inference framework is shown in Fig. 2.

4. System Integration

The interface provided by Jena framework is an application based on Java platform, but it is not suitable for direct use in the Java Web environment. It needs to be modified. To integrate it in the web environment, its functionality should be re-encapsulated and combined with the Spring framework so that it is suitable for inference and parsing in the web environment.

The queries and inferences of Jena are placed in the model layer of the Spring framework, and the rules-based inference functions are re-encapsulated into a JenaModel class based on the Spring's control and model layers. The JenaModel class is an inheritance of the OntModel class (whose parent class is Model class) in Jena. By inheriting from that class, we can access statements in RDF data set and access and manipulate various data objects including classes, properties, and instances (individuals) in the ontology. Jena's inference is done through the reasoner class. If the reasoner class fits the factory class of the ReasonerFactory interface, which is attached with a set of RDF data to create a inference model. By encapsulating all of the RDF data into two components - the schema and instance data. This can enable the implementation of reasoning to use a set of schema data to effectively use multiple sets of instance data for reasoning. In Spring, the operation of database and files is mainly done at the model layer, so the query and inference functions of Jena are put there, and the required data is fed to the control layer.

5. Conclusions

The continuous development of information technology brings new technologies and means to continuously enrich the ways people solve problems. By introducing RDF into knowledge representation in the welding process expert system and storing knowledge base in HDFS, we can solve the problem of big data storing. By bringing the Jena framework into the reasoner for further optimization of the CO_2 gas shielded welding process to reduce spatter, we can increase the accuracy of the welding process generated by the welding process expert system. Combining with the Spring framework and HTML5, a user interface with good experience is achieved. Thereby, we can achieve the full realization of the expert system from the Internet to the mobile Internet, providing a new idea for the development of expert system.

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