AC 2009-960: EDUCATING ENGINEERS ON GLOBAL ISSUES THROUGH U.S.-INDIA RESEARCH EXPERIENCE PROGRAM CASE STUDIES

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Educating Engineers on Global Issues through US- India Research Experience Program Case Studies

Abstract

Engineering students can understand global issues better in their curriculum if they are able to see examples of real-world issues happening in the industry. This paper describes the experiences in conducting a collaborative non-destructive evaluation (NDE) project between students and faculty members of Auburn University, Auburn, Alabama; a major laboratory in India; and Indian Institute of Technology (IIT), Madras, India. The team at the NDE imaging and modeling lab at the Indian research center was keen in developing a robust algorithm for their automatic defect recognition (ADR) system for welds. The main problems the team faced in analyzing weld radiographs were (1) detecting weld defects in the presence of weld ripples and (2) detecting very faint defects occurring at the edge of the weld seam. The managers at this center wanted the team to develop new methodologies to identify defects in welds for analyzing the radiographs and solve the above problems. In order to bring this real-world issue into engineering classrooms, the authors developed a multi-media case study. The case study brings the problem to life in classrooms using video, audio, and pictures. The details of the case study are discussed in the paper

Keywords: real-world, collaborative, global issues, automatic defect recognition, case study

Introduction

Case studies have traditionally been used to show that real-world decisions need to be made so that financial goals, technical needs, safety factors and credibility issues are simultaneously considered and weighed.[1, 2] For the past ten years, the Laboratory for Innovative Technology and Engineering Education (LITEE) at Auburn University has been producing case studies in engineering, business and technology areas and has been successfully implementing them at Auburn and several other universities with a very high percent of positive feedback on them.

The graduate-level courses in the LITEE curriculum are a sequence of two classes that act as a case study development project for students participating in the International Research Experience for Students (IRES). The first semester course provides an introduction to how case studies are developed. The second semester is a fieldwork course in which the students actively work with industrial partners in India to research a problem and turn the results into a multimedia case study.

This paper discusses how the IRES program is conducted as a two-semester sequence at Auburn University. It also describes how a research problem at a company was converted into a case study for implementation in a classroom environment. In the next paragraph we give details about the IRES program.

International Research Experience for Students (IRES)

A major goal of the IRES project conducted at Auburn University is to integrate research into teaching and learning at the undergraduate level and thus infuse education with the excitement of discovery. In order to accomplish this goal, we used the case study methodology to develop new instructional materials that can be used in undergraduate classrooms. The LITEE team works with industrial partners to identify a suitable problem and bring it alive in the classroom by creating a multimedia case study. This is then tested for pedagogical value and content with faculty and students at different institutions. The multimedia case study CD-ROMs make it possible for students to visualize the case study problem and, in some cases, even hear the voices of those charged with making the original decisions. Photos and videos of the machinery and equipment in the actual plants are included.

A case study typically is a record of a technical and/or business issue that has actually been faced by managers together with surrounding facts, opinions, and prejudices upon which management decisions have to depend. These real and particularized cases are presented to students for considered analyses, open discussion, and final discussion as to the type of action that should be taken. The fundamental principles underlying the case study method of teaching as summarized by Barnes et al.[3] are:

1. *The primary of situational analysis:* Analysis of some specific situation forces the student to deal with "as is" and not the "might be."
2. *The imperative of relating analysis and action:* The traditional academic focus has been to know; the practitioners' focuses have been on action. The case study method of instruction seeks to combine these two activities.
3. *The necessity of student involvement:* The active intellectual and emotional involvement of the student is a hallmark of case study method. That involvement offers the most dramatic visible contrast with a stereotypical lecture class.
4. *A nontraditional instructor role:* The instructor's role is not so much to teach students as to encourage learning. His/her role is more of a facilitator and he/she has to be both a teacher and a practitioner.
5. *The development of an administrative point of view:* The students develop an understanding of the problem from a holistic point of view and not from an engineer's perspective alone.[4]

The IRES project goals and educational objectives are shown in Table 1[5]. The two-semester sequence of classes is offered through the mechanical engineering and management departments at Auburn University.

Project Goals (What will we do?)	**Educational Objectives (What will students achieve?)**
Develop a case study that introduces engineering students to the complexity of real-world problems in collaborative global	*The students will be expected to:* *- learn how companies use innovative research in the design of products and systems*

engineering R&D projects	*- learn how companies form and manage teams to design engineering products and services in globally dispersed R&D units.* *- work in teams, thereby enhancing their team building, interaction, and interdisciplinary skills.*
Develop instructional materials that help visualize research on global R&D issues	*The students will experience:* *- Synchronous learning opportunities such as triggering learning interest, learning from others, and working in teams.* *- Asynchronous learning opportunities such as solving challenging problems, accessing vast information sources, learning discovery-based educational experiences safely, and enhancing peer-to-peer education.*

Table 1: Project Goals and Educational Objectives

Figure 1 provides a course map for these courses. These courses prepare students for an intensive research program that instructs them on using research methodologies to analyze a problem that happened in an industry, come up with solutions, and then document them using a multimedia case study. It consists of a defined sequence of classroom sessions combined with real-world, project-based activities. The classroom sessions are interactive, intense, and intimate and provide the students with the broad base of knowledge they need to develop a multimedia case study. It teaches the students to develop case studies when working with a team. The students work on a number of case studies chosen from the LITEE case studies (available at www.liteecases.com) in order to understand how to analyze a case study. They are also taught how to develop a multimedia case study by hands-on sessions with a case study template. The project activities give the students valuable experience in leading teams and working with industry managers and engineers on issues of relevance to technology-based organizations. The real-world focus of this course allows the students to apply what they learned in this class to their future jobs. In the next sections, we discuss how the Automatic Weld Inspection case study was developed following the process outlined in this section. The program directors of the Auburn University IRES program made contacts with a major research center in India and faculty members at the Indian Institute of Technology, Madras, so that a research project could be conducted there.

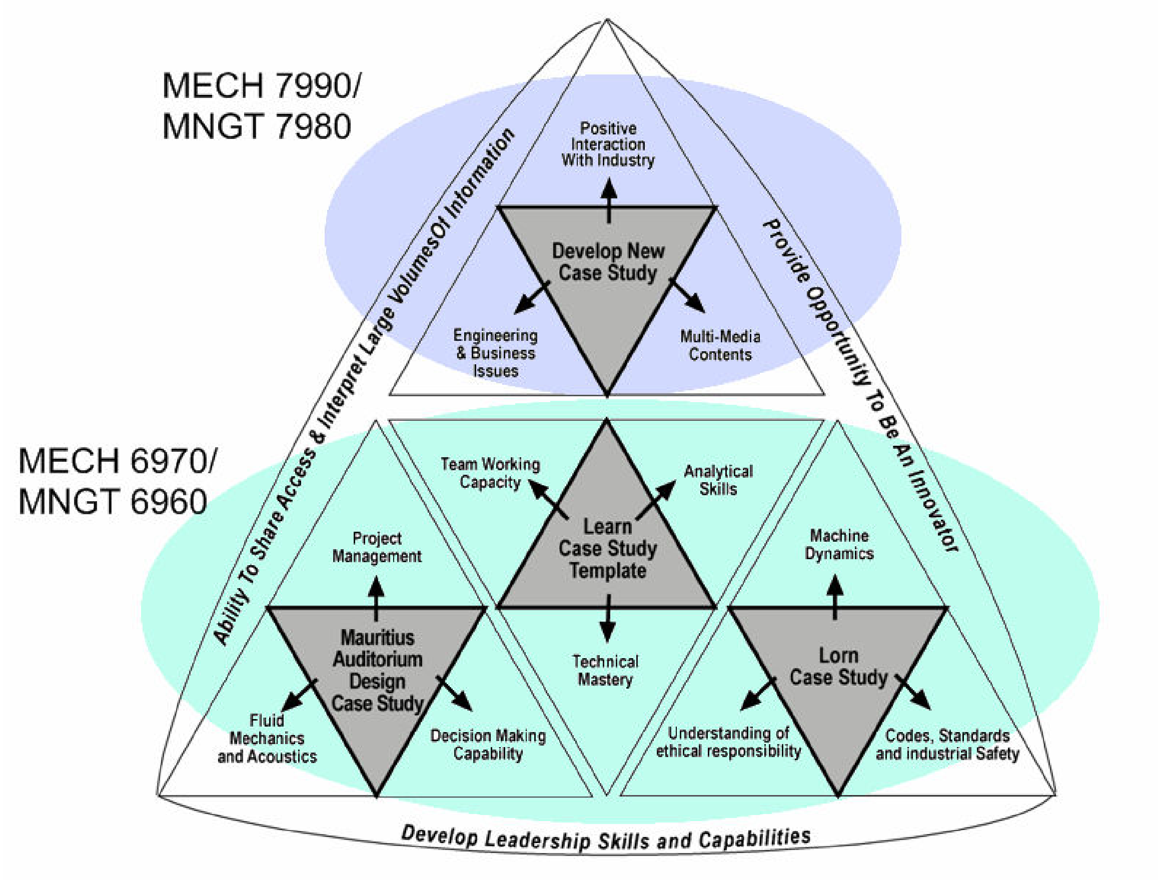


Fig 1.Course Map for IRES Project

<u>Development of Automatic Weld Inspection Case Study</u>

The Non-Destructive Evaluation (NDE) Imaging Lab at the research center conducts advanced research in the areas of imaging for non-destructive evaluation modalities such as ultrasound, electromagnetics and X-ray, primarily for defect detection and characterization. Most NDE modalities offer either a one-dimensional signal, a 2-D image or a 3-D stack of images. The lab utilizes the core competency in the areas of NDE modalities, signal/image processing and analysis, pattern recognition and correlation in accomplishing advanced inspection goals related to defect detection and characterization in industrial components and infrastructure.[6] The NDE Modeling Lab conducts advanced research in the area of modeling for NDE. Physics-based modeling and simulation for NDE plays a vital role in understanding how various modalities (such as X-ray, eddy current, ultrasound and optics) can be used for various industrial inspection applications.[7]

By working with the management team at the research center, the project team identified three specific educational objectives of this case study:

- showcases the importance of weld testing in the real world and the after-effects if a weld failure occurs

- gives information about the types of welding defects and also suggests a process to identify the welding defects in certain limiting cases
- students get an opportunity to learn about non-destructive testing and evaluation of welds using image processing techniques used in automatic weld defect detection systems

Introduction to Problem: Need for Inspecting Welds

Faults in welding can lead to loss of equipment and life. For example, the explosion and fire that occurred at the Marcus Oil facility in Houston, Texas, in December 2004 resulted from faulty welds in a pressure vessel.[8]

Chemical Safety Board (CSB) investigators determined that the failed vessel, known as Tank 7, had been modified by Marcus Oil to install internal heating coils, as were several other pressure vessels at the facility. Following coil installation, each vessel was re-sealed by welding a steel plate over the two-foot-diameter temporary opening. The repair welds did not meet accepted industry quality standards for pressure vessels. The investigation revealed that Marcus Oil did not use a qualified welder or proper welding procedure to reseal the vessels and did not pressure-test the vessels after the welding was completed. The investigation also showed that the weld used to close the temporary opening on Tank 7 failed during the incident because the repair weld

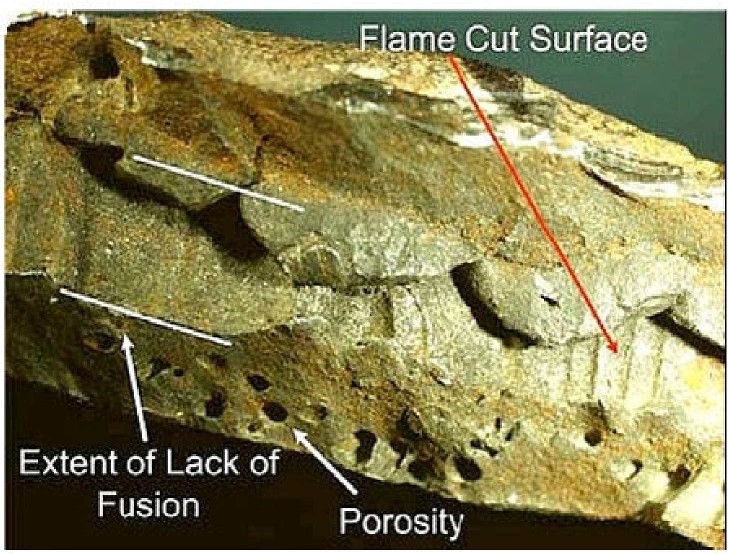


Figure 2.Recovered patch plate weld from failed Tank 7

did not meet generally accepted industry quality standards for pressure-vessel fabrication (Figure 2)[8] The original flame-cut surface was not ground off the plate edges before the joint was re-welded, and the weld did not penetrate the full thickness of the vessel head. Furthermore, the welds contained excessive porosity (holes from gas bubbles in the weld). These defects significantly degraded the strength of the weld. The fire spread back into the damaged tank and caused a violent explosion, which propelled the 25-ton vessel more than 150 feet, where it came to rest against a warehouse on an adjacent property (Figure 3)[8].

Figure 3.The scene following the explosion

In 1997, the Williams-Renault racing team was put on trial for manslaughter under Italian law. They were accused of being responsible for what the prosecutor said was a faulty steering column weld on their racing car. Welding is a large industry, and welding expenditures in the U.S manufacturing, mining and construction industries were about $34 million for the year 2000.[9] General Electric Aircraft Engines, Madisonville, Kentucky produces 2.5 million radiographs per year, of which 70% are weld radiographs. The GE Inspection technologies X-ray testing machines market is $100 million; 80% are welds. The power sector produces more than 500 welds per day. Bharat Heavy Electricals, India, produces more than 1000 pipe welds per day for their boilers, nuclear reactors, etc.

It is critical to inspect these welds without destroying them; non-destructive testing is critical in ensuring the quality of the welds. As size and weight decrease and the factor of safety is lowered, more and more emphasis is placed on better raw material control and higher quality of materials, manufacturing processes, and workmanship. A producer of raw material or a finished product frequently does not improve quality or performance until that improvement is demanded by the customer. The pressure of the customer is transferred to implementation of improved design or manufacturing. Non-destructive testing is frequently called on to deliver this new quality level.[10]Non-destructive tests are used to determine the direction, amount, and gradient of stresses in mechanical parts as applied in the field of experimental stress analysis. These play a very important role in the design of lighter, stronger, less costly and more reliable parts.[11]

Problem statement

The main problem faced by the research center with the weld radiograph images was detecting the defects in the presence of weld ripples and also when the defects were faint. The three types of defects identified were lack of fusion, lack of penetration and scattered porosity. The goal was to develop an algorithm so as to aid in the automatic defect recognition system. An exhaustive research on literature related to weld ADR showed that there was no commercial system available in the market that could automatically detect the faint defects in the welds. Figures 4 and 5 show examples of defects in welds.

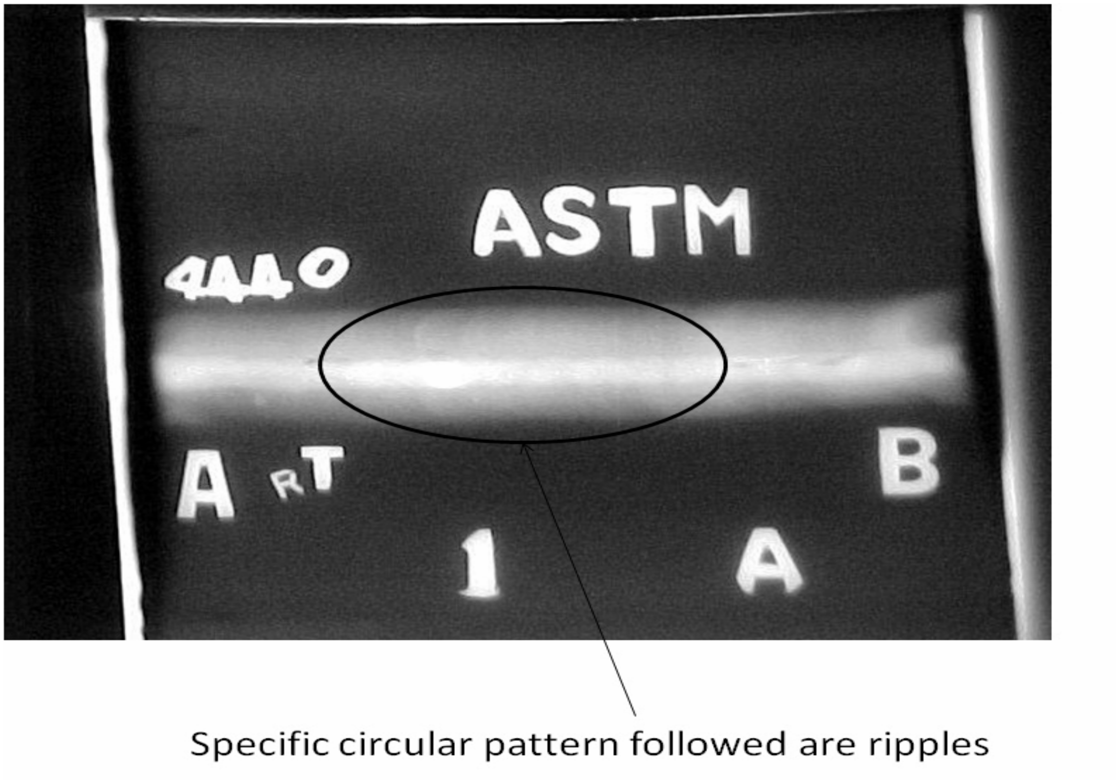


Figure 4.Weld radiograph with ripples

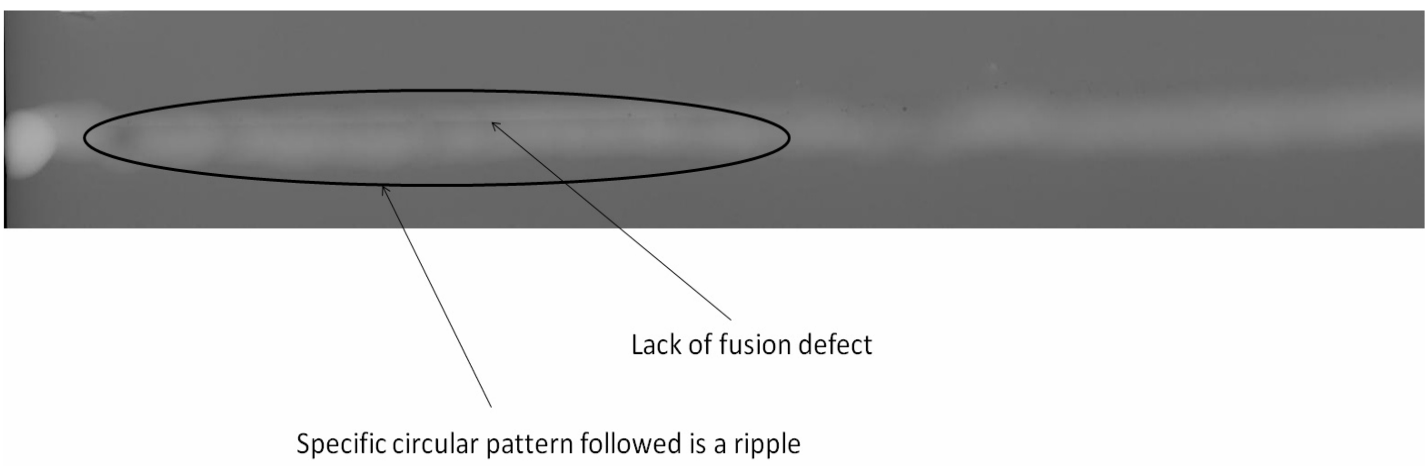


Fig 5.Weld radiograph image with ripples and faint indication of lack of fusion defect

Automatic Defect Recognition (ADR) System

Figure 6 shows a block diagram of an Automatic Defect Recognition (ADR) system. The processes used in an ADR system are: preprocessing, segmentation of the defects, feature extraction, and classification of the defects. Each of these processes will be described next. Then an algorithm is proposed to improve the process.

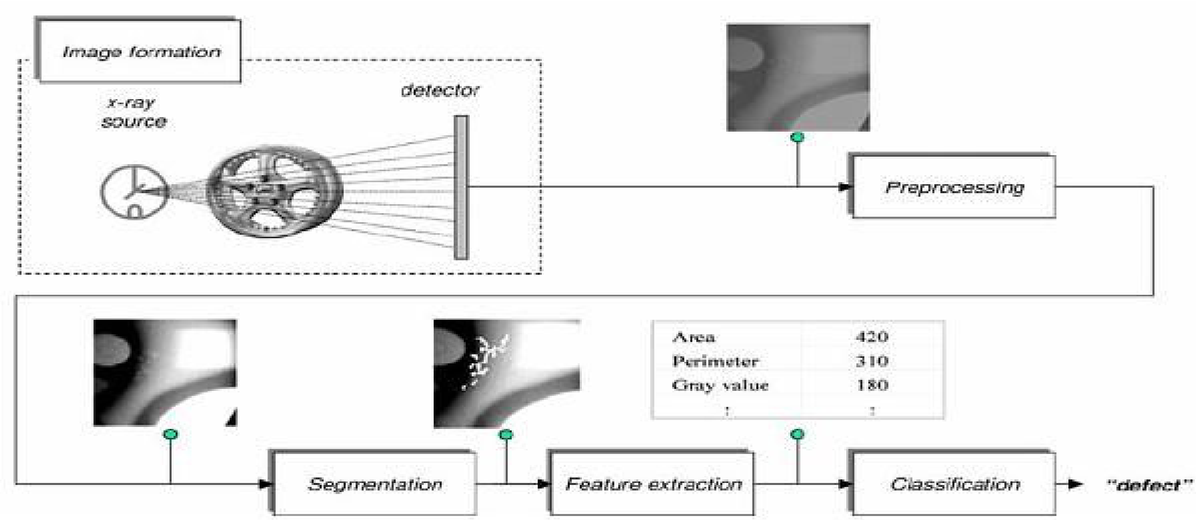


Fig 6.Block Diagram of an Automatic Defect Recognition (ADR) system[12]

Preprocessing: Preprocessing prepares the acquired raw digital image for the defect detection stage by reducing noise, correcting for background trends (shading correction) and removing geometric structures that otherwise would adversely affect the defect-detection stage. Noise reduction (frame averaging, mean filter, median filter) and contrast enhancement (contrast stretching and histogram equalization) are normally performed in this process.[13]

Segmentation of the defects: The techniques that are used to find the objects of interest are usually referred to as segmentation techniques—segmenting the foreground from background. Morphological processing, background subtraction method, profile-anomaly detection, segmentation by thresholding, edge detection techniques, template matching and matched filters are some of the methods of segmentation.[14]

Feature extraction: When the input data to an algorithm is too large to be processed and is suspected to be notoriously redundant (much data, but not much information), then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called features extraction. If the features extracted are carefully chosen, it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full-sized input. Extraction of defect features is one of the steps involved in weld ADR prior to the defect classification, where the defects are measured. One measurement is the value of any sizeable property of the defect. A feature is a function of one or more measurements, which are registered in the computer to dimension any significant characteristic of the defect. Some of the features that serve as classifier data inputs are location, shape, length, density, aspect ratio, and roundness. Some of the geometric feature extraction methods are edge detection, corner/interest point detection, curve fitting or local curve estimation, model based feature detection, region detection, and feature extraction using textures.

Classification of the defects: In the defect-classification stage, the defect pixels identified from the previous stage are grouped into connected regions (connectivity analysis), their characteristics quantitatively measured, classified into different types (expert systems are used for this), and finally a pass/fail decision made based on the defined inspection criteria. The results can be stored in a database and used for production process improvements. Artificial neural networks (ANN), fuzzy systems, and non-linear classifiers are some of the methods for classifying the defects.[14]

Proposed Algorithm

Figure 7 provides an algorithm that can be used to improve the process described above. The steps in the algorithm are:

- The given digital radiographic image is analyzed and only the welded part is cropped removing the unwanted information.
- The cropped weld part is filtered and contrast-enhanced to reduce the noise and to show the defect out properly.
- The pre-processed image is then divided into sub-images.
- Region-growing is applied to the sub-images which clearly showcases the defects.
- Then the processed sub-images are concatenated to get a final image.

This algorithm was used to analyze the radiographs of multiple welds to identify whether it led to improved identification of faults in welds. Figures 8a through 8d take an image and use the algorithm to identify the defect. As can be seen, Figure 9 reveals several defects in the weld which are not normally identifiable using traditional methods. This algorithm was used to analyze 33 radiographs and was 90% efficient in detecting the defects in these radiographs

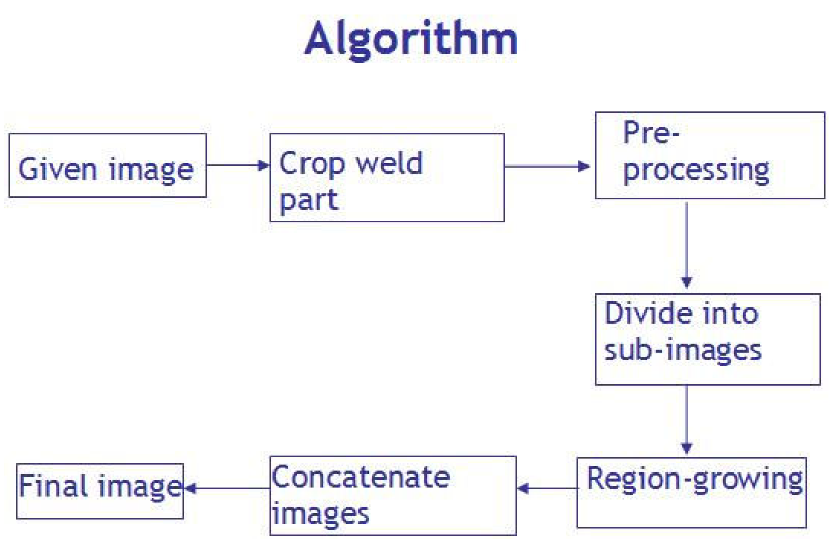


Fig 7.Block Diagram of the proposed algorithm

The following images are different views of the input and output images used:

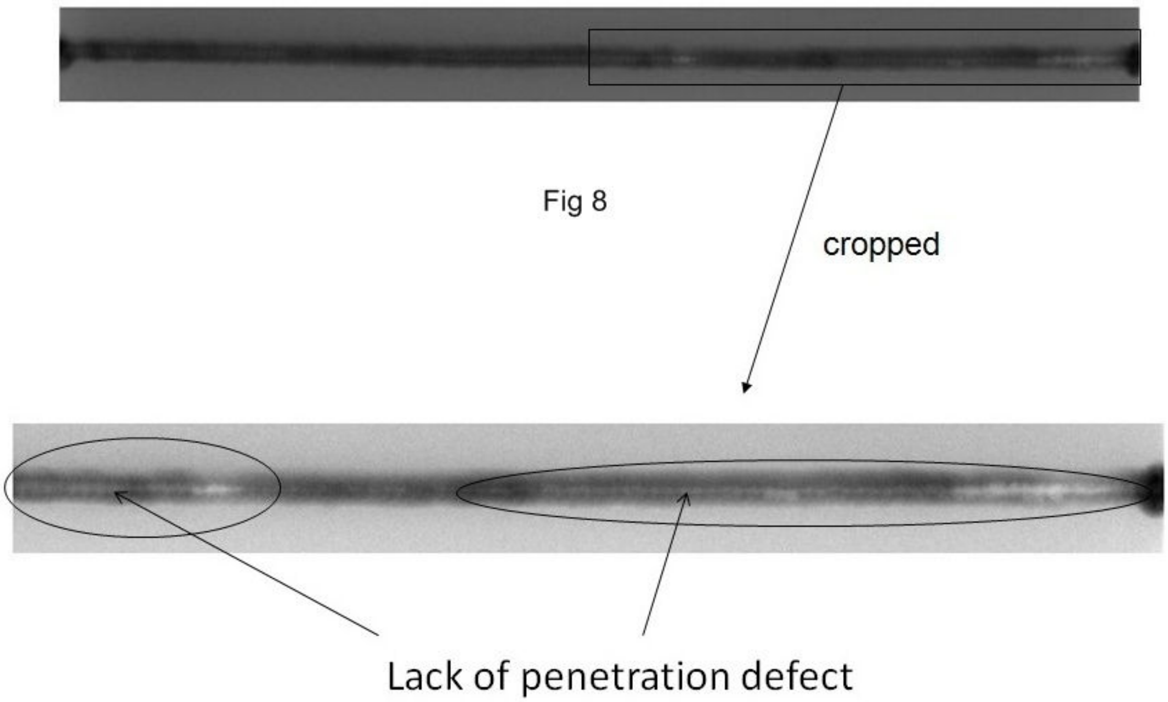
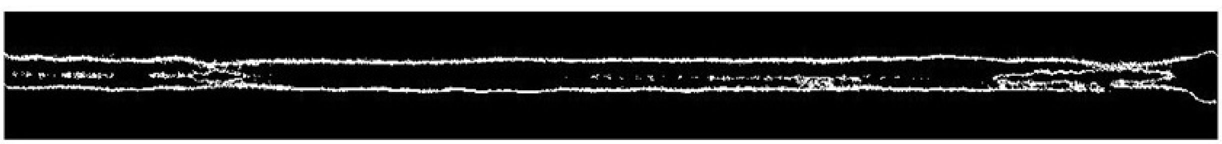


Fig 8

Fig 9

Fig 8 shows a weld Radiograph with the weld area and the region of interest to be cropped

Fig 9 shows a pre-processed image of cropped region showing the lack of penetration defects



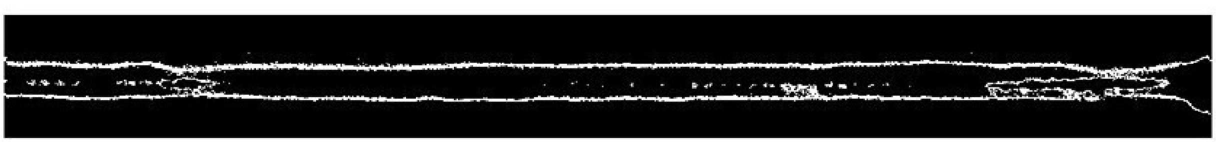


Fig 10 shows the final Image after applying the proposed algorithm

Development of Multi-Media Case Study

In the next sections, we provide details of how a case study was developed so that students can use it in classrooms. Based on a case study development format available to the LITEE development team, the researcher developed a case study based on the details provided above. The multimedia case study was developed with the following clickable tabs:

- Overview
- Problem Statement
- Objectives
- Credits
- Weld ADR
    - Introduction of ADR
    - Need for Weld ADR
    - Background
- Problem
    - Introduction
    - Types of Defects
    - Earlier Solutions
    - Proposed Algorithm
    - Results
- Tools
    - Basics of ADR
    - Basics of Welding
    - Basics of Image Processing
    - NDT and Imaging
    - Glossary
    - References
- Assignments
    - Assignment 1

  - Assignment 2

- Search
- Sitemap

A glossary section provides information on the technical terms used in the case study. An assignment section was developed and provides the following assignment to students. The students are expected to be divided into teams and discuss the following scenarios:

Group A: Representing one of the teams at the company: Critique and comment the proposed algorithm

Group B: Representing one of the teams at the company: Find out the flaws in the algorithm and come up with a new idea of detecting defects.

Group C: Representing one of the teams at the company: From the past research work done in automatic defect recognition for welds; determine which one is the most feasible NDT method used for the process.

Group D: Representing one of the teams at the company: Find out the other types of defects in welds and check whether the algorithm works for those types of defects.

Group E: Conduct a feasibility study on the methods used for automatic weld defect detection and find out the best method suitable for the given images.

The case study is available for use in classrooms from www.liteecases.com.

Summary

The innovative and unique features of this project are that:

- It gives an opportunity to a graduate student to work in the real world with a global company thereby preparing him/ her for a better future,
- It provides a company chance to provide an internship opportunity to a student and then to share the results of the research with more students by the development of the case study,
- It provides the LITEE team an opportunity to develop a case study based on a real-world problem,
- It provides undergraduates a chance to work in teams to analyze the case study thereby reinforcing their engineering capabilities.

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