First Libyan International Conference on Engineering Sciences & Applications (FLICESA_LA)
13 – 15 March 2023, Tripoli – Libya

Automated Arc Welding Defect Detection for Industry 4.0 Machine Vision System

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Abstract
A very low latency automated defect detection solution is for robotic gas metal arc welding (GMAW) in heavy equipment manufacturing. The camera-based solution runs on the edge, detects weld porosity defects using a proven AI algorithm, and can be used to stop the robotic arm immediately in case an anomaly is identified. This allows manufacturers to find weld defects and reduce delays in the production process, optimize costs, and increase overall productivity. Automated Arc Welding Defect Detection uses a deep neural network based interference engine to detect welding defects in a way not possible with the human eye and is tested to deliver high accuracy. It is powered by scalable Intel® Core™ i7 processors and uses Intel® Movidius™ VPUs and the Intel® Distribution of OpenVINO™ toolkit to detect arc-welding defects with very low latency and high accuracy. "AI and machine vision technologies are transforming traditional manufacturing processes in ways we could never imagine before. Robotic welders equipped with Artificial Intelligence "AI" -driven machine vision can transform quality control and give manufacturers a competitive advantage. Due to tremendous production volume, the designers looked for new ways to catch flaws during the welding process. The new technology turned to ADLINK, a global manufacturer of edge computing solutions. This paper discusses the ADLINK's AI and Computer Vision "CV" powered Edge Arc Welding Defect Detection solution gives Deere the ability to watch the weld pool in real time to find and correct issues as they occur, where the toolkit software code is described.

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Key words
Gas Metal Arc Welding (GMAW)- Defect Detection - Industry 4.0 - Artificial Intelligence "AI"- Quality Control "QC" - Intel OpenVINO Toolkit – Computer Vision "CV"- ADLINK Platform.

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I. INTRODUCTION

Robotic arc welders are the workhorses of the factory floor, fusing steel in the most extreme conditions. As tough as they are, robots cannot QC their work, even when common weld defects such as porosity occur. In addition, when flaws are not caught in the welding process, disruptive and costly rework or scrapping material may be required. Traditional quality control includes highly skilled weld technicians who use visual and auditory indicators to detect porosity. However, these experts are limited in what they can catch. Miles of welds come down the assembly line, making it impossible to visually inspect each one. In addition, they do not have the ability to see beneath the surface of the weld without radiographic and ultrasonic technologies. As a result, items go out factory doors that can later become warranty claims. Fortunately, innovative technologies can provide a solution. Robotic welders equipped with AI-driven machine vision can transform quality control and give manufacturers a competitive advantage.

II. Visual Defect Detection Catches Flaws

The agricultural equipment manufacturer John Deere is a great example. The company uses a gas metal arc process to weld the high-strength steel required to build its machinery. Across 52 factories around the world, hundreds of robotic arms use millions of weld wire pounds annually. With this tremendous production volume, the company looked for new ways to catch flaws during the welding process. The company turned to ADLINK, a global manufacturer of edge computing solutions.
ADLINK's AI and computer vision powered Edge Arc Welding Defect Detection solution gives Deere the ability to watch the weld pool in real time to find and correct issues as they occur. "Machine learning gives John Deere a better understanding of the quality across every single weld," says Daniel Collins, Senior Director of Edge Solutions for ADLINK.

"That is very powerful stuff from a warranty and messaging perspective."

III. Rugged Hardware + Pre-trained Software

The arc-welding platform comprises a combination of software and hardware, based on an industrial-grade machine vision platform using Intel® Core™ processors and Intel® Movidius™ Myriad™ X VPUs. MeltTools welding cameras—designed to withstand high temperatures and intense light—are mounted on the robotic arm, just 12 to 14 inches from the weld. A pre-trained machine learning model uses integrated ADLINK Edge IoT software that can capture, stream, process, understand, and act on vision data. The ADLINK architecture allows manufacturers to plug in modular

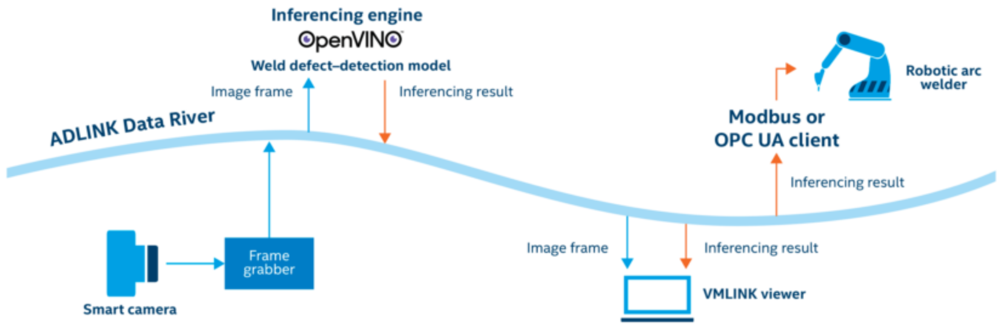

Figure 1. Edge devices collect real-time insights for inspecting welds and providing an ability to stop the process if it finds a defect.

"The software is a big reason why the platform works," says Collins. "It consists of the Intel® OpenVINO™ Toolkit inference engine, which is the machine vision calculator, and ADLINK Edge, which is broken up into several different applications. These applications do everything from ingest the camera data, stream it to the inference engine, understand the results, and take action. And this all happens in real time using the ADLINK Data River or the Edge communication layer." A decision-making app waits for the inference engine's results to assess the quality of a weld. If it says to stop a weld, a DIO app fires a 24-volt signal to the robot and pauses the weld. At the same time, it sends an alert to the factory floor manager that the weld has been stopped. "If a quality issue was identified after the fact in a batch, likely they would have to pull all the welds from that batch to further inspect and rework them. That could even mean scrapping entirely and rebuilding from scratch," says Collins. AI Brings Business Opportunities to Sis The robotic arc welding space is growing, and large manufacturers are moving away from manual weld quality practices, which creates a huge opportunity for systems integrators. "If you do a quick look at what is available from a robotic welding quality inspection perspective, you won't find much that inspects during the weld job," Collins says. "You'll find various components here and there, like cameras and models. What you won't find are all the components or building blocks bundled together in a single offering." Designed for PoCs, the ADLINK kit includes machine vision algorithms that can identify one of the roughly 10 quality inspection issues that are pervasive in welding. To customize the solution for its customer, SIs may need to do some configuration and retraining. "A customer in a new environment may be able to identify porosity, for example, using the out-of-the-box solution," says Collins. "Likely however, we would need to do some model retraining to increase the accuracy for that environment. We did the legwork required to identify all the right components. The SI's job is to configure them in such a way that their client gets immediate value once deployed." In addition, many manufacturers are interested in weld quality inspection as a service, adds Collins. "There's a potential opportunity to offer managed services," he says. "That combined with an industry that's growing and the need to configure and retrain for every customer environment, is quite a bit of services revenue for an SI." Computer vision and machine learning turn robotic welders into the superheroes of the factory floor, spotting defects that would have otherwise gone unnoticed. By leveraging AI technology, manufacturers and the SIs that serve, they gain an advantage in today's competitive marketplace.

Figure.2 ADLINK Edge IoT software and the Intel Distribution of Open VINO toolkit action recognition model

“A customer in a new environment may be able to identify porosity, for example, using the out-of-the-box solution,” Thus, we should do some model retraining to increase the accuracy for that environment. The work required to identify all the right components had been done. The SI’s job is to configure them in such a way that their client gets immediate value once deployed.” In addition, many manufacturers are interested in weld quality inspection as a service, “There’s a potential opportunity to offer managed services, combining with an industry that is growing and the need to configure and retrain for every customer environment, and is quite a bit of services revenue for an SI.” Computer vision and machine learning turn robotic welders into the superheroes of the factory floor, spotting defects that would have otherwise gone unnoticed. By leveraging AI technology, manufacturers and the SIs that serve, they gain an advantage in today’s competitive marketplace.

IV. Weld porosity detection

Using Case and High-Level Description

This is a porosity weld recognition model. It runs on a video stream capturing welding tip and reports whether no welding is happening, produced weld is good or weld is porous. Figure. 3 shows the porosity weld recognition model

Figure. 3 weld porosity recognition model

Specification

Metric	Value
Clip classification accuracy	97.14% (internal test set)
Temporal smoothing window size	16
GFlops	3.636
MParams	11.173
Source framework	PyTorch*

Inputs

Image, name: input, shape: 1, 3, 224, 224 in the format B, C, H, W, where:

- B - batch size
- C - number of channels
- H - image height
- W - image width

Expected color order is BGR.

Outputs

The features is a blob with the shape 1, 3 containing logits for three output classes ("no weld", "normal weld" and "porosity").

The Visual Studio C++ manipulation software project uses firmware that can provide query sensor port values, and machine parameters with this example:

?

```
#include "stdio.h"
#include "Dynamixel.h"
#include "SerialPort.h"

int _tmain(int argc, _TCHAR* argv[])
{
   int error=0;
   int idAX12=17;

   SerialPort serialPort;
   Dynamixel dynamixel;

   if (serialPort.connect(L"COM1")==0) {
      dynamixel.sendTossModeCommand(&serialPort);

      int pos=dynamixel.getPosition(&serialPort, idAX12);

      if (pos>248 && pos <1023)
         dynamixel.setPosition(&serialPort, idAX12, pos-100);
      else
         printf ("nPosition <%i> under 248 or over 1023", pos);

      serialPort.disconnect();
   }
   else {
      printf ("nCan't open serial port");
      error=-1;
   }

   return error;
}
```

The same method could be used to create the command to write the AX-12+ position.

V. CONCLUSION

ADLINK and Intel have created an automated weld-defect detection solution based on ADLINK's EOS vision system with ADLINK Edge IoT software and the Intel® Distribution of OpenVINO™ toolkit action recognition model, capable of automatically detecting porosity defects from video frames in a way not possible with the human eye. Using a neural network–based inference engine, the solution can not only detect defects in real time but also automatically stop the welding process via robot actuation before the defect is prolonged and the part is damaged beyond repair. The model could be retrained to detect additional types of defects in the welding process. This innovative solution supports a smarter factory, helping to create production lines that are built for Industry

4.0. The solution consists of a pretrained machine-learning model from Intel on the ADLINK EOS-1620 machine vision platform featuring Intel® Core™ i7 processors and Intel® Movidius™ Myriad™ X.

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