US00RE45398E

(19) **United States**
(12) **Reissued Patent**
Wallace

(10) **Patent Number: US RE45,398 E**
(45) **Date of Reissued Patent: Mar. 3, 2015**

(54) **SYSTEM FOR TRACKING AND ANALYZING WELDING ACTIVITY**

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(21) Appl. No.: **14/177,692**

(22) Filed: **Feb. 11, 2014**

Related U.S. Patent Documents

Reissue of:
(64) Patent No.: **8,274,013**
Issued: **Sep. 25, 2012**
Appl. No.: **12/719,053**
Filed: **Mar. 8, 2010**

U.S. Applications:
(60) Provisional application No. 61/158,578, filed on Mar. 9, 2009.

(51) **Int. Cl.**
B23K 9/06 (2006.01)

(52) **U.S. Cl.**
USPC .... **219/137 R**; 219/124.34; 219/130.33; 219/136; 219/130.01

(58) **Field of Classification Search**
CPC B23K 9/0953
USPC .... 257/137 R
See application file for complete search history.

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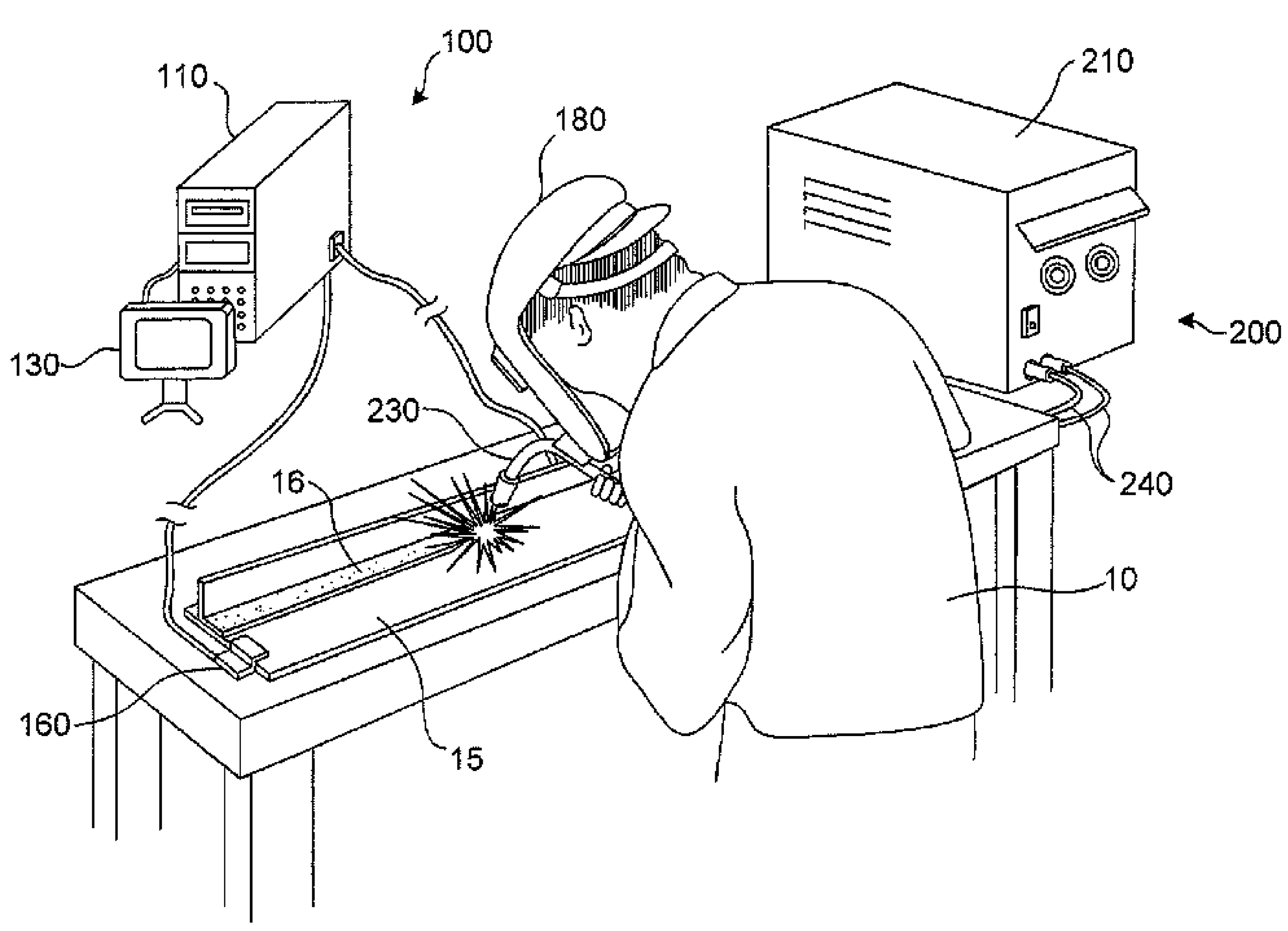
(57) **ABSTRACT**

A system and a method for tracking and analyzing welding activity. Dynamic spatial properties of a welding tool are sensed during a welding process producing a weld. The sensed dynamic spatial properties are tracked over time and the tracked dynamic spatial properties are captured as tracked data during the welding process. The tracked data is analyzed to determine performance characteristics of a welder performing the welding process and quality characteristics of a weld produced by the welding process. The performance characteristics and the quality characteristics may be subsequently reviewed.

195 Claims, 6 Drawing Sheets



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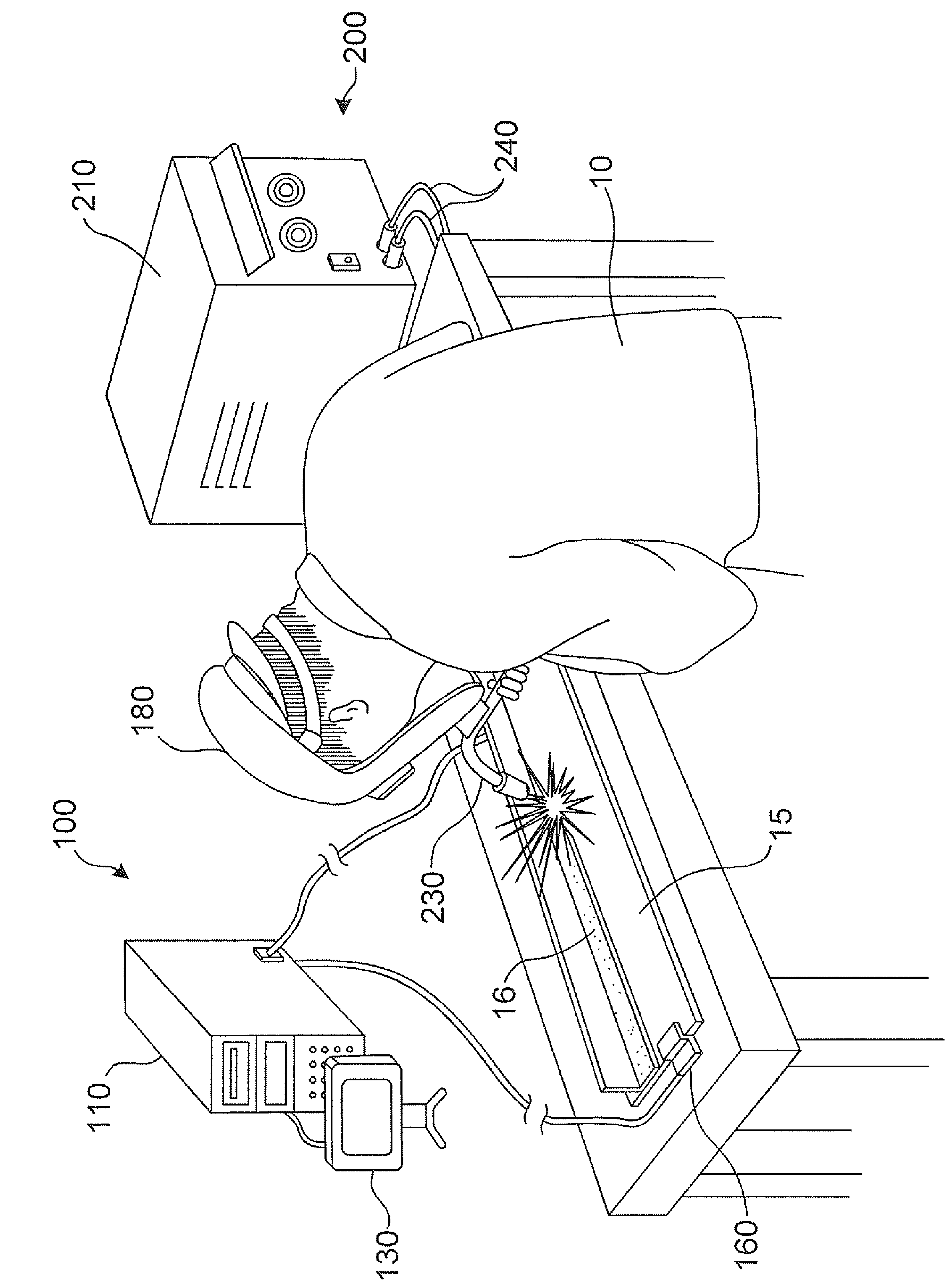


FIG. 1
AMENDED

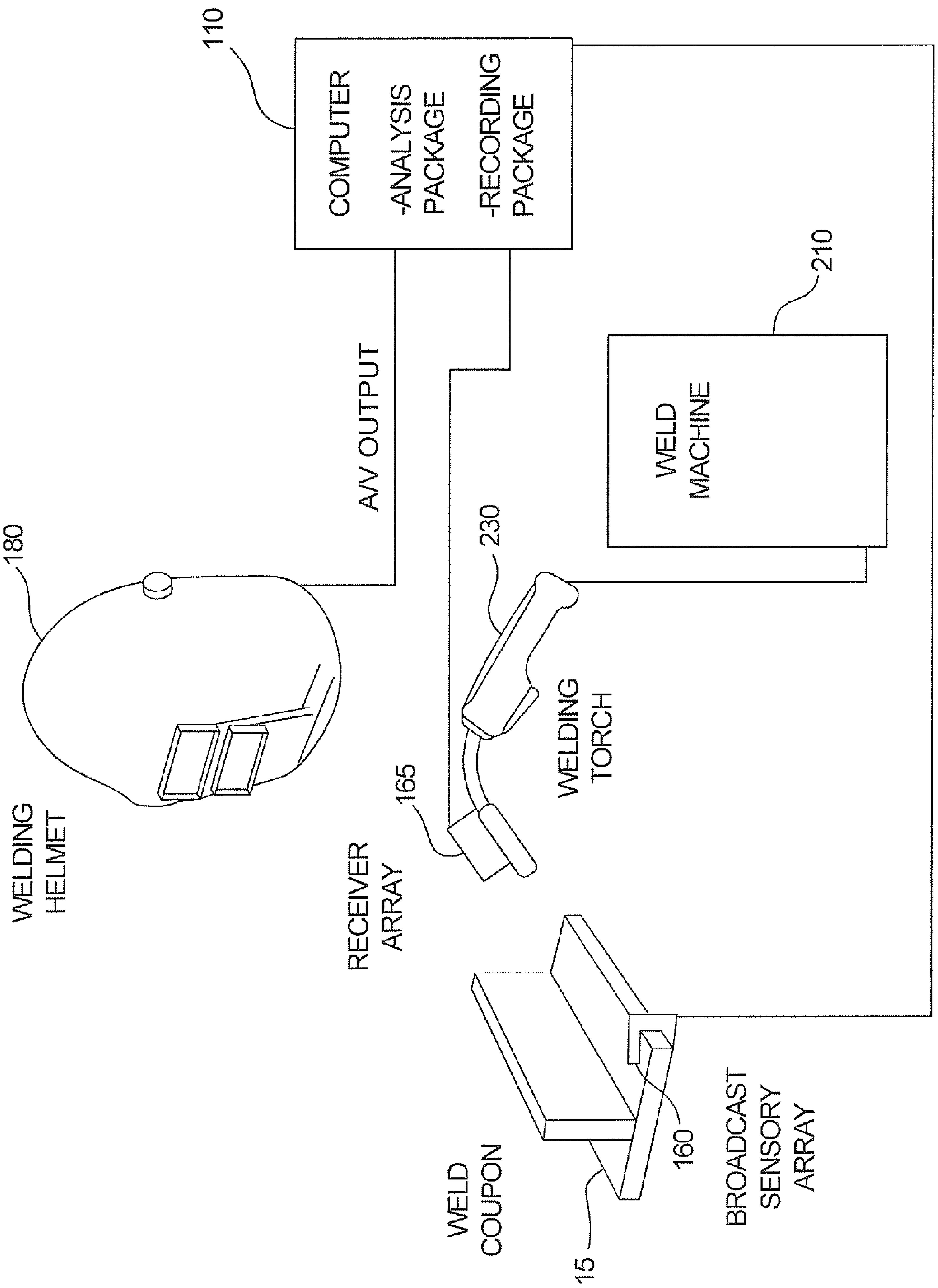


FIG. 2
AMENDED

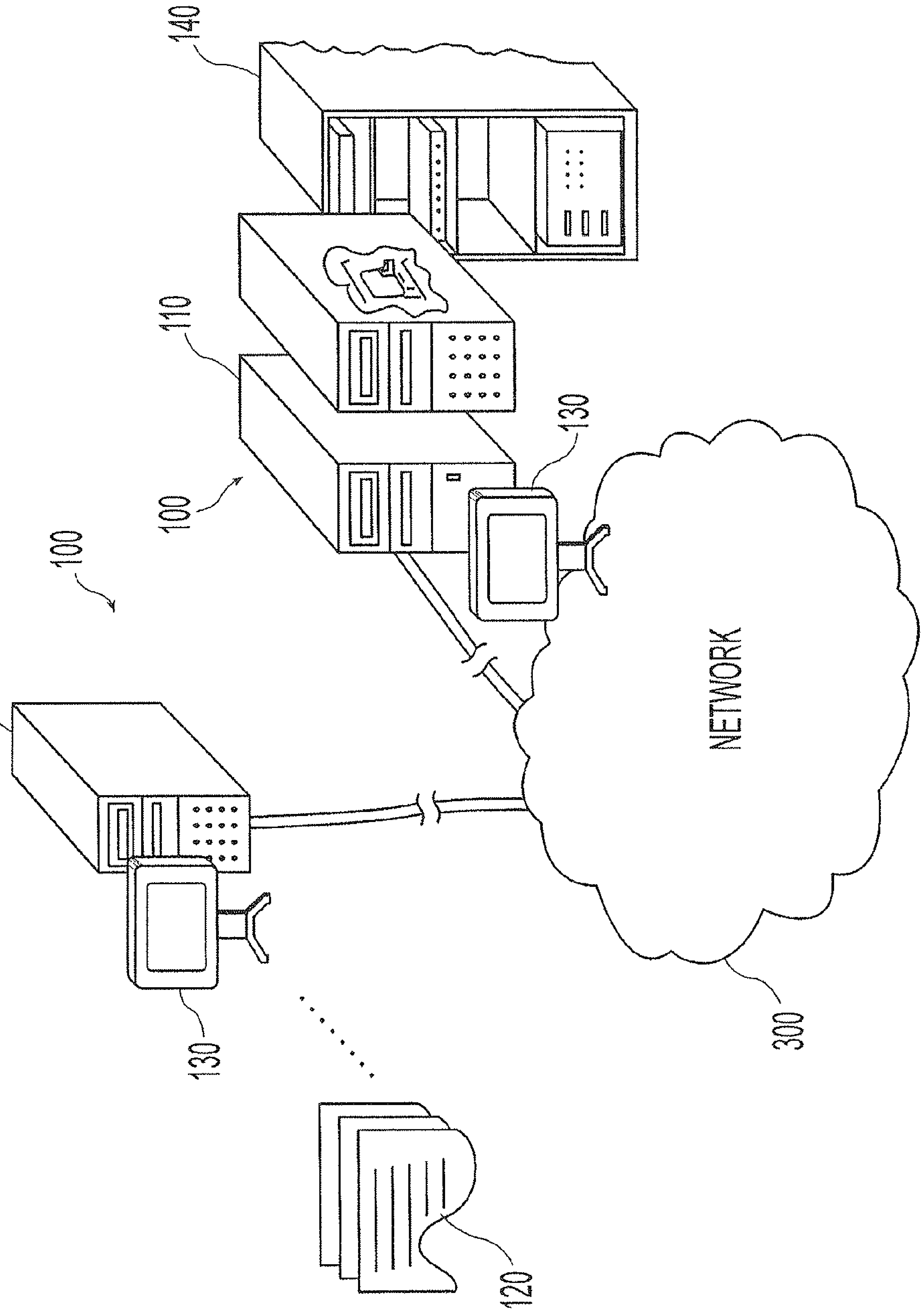


Fig. 3

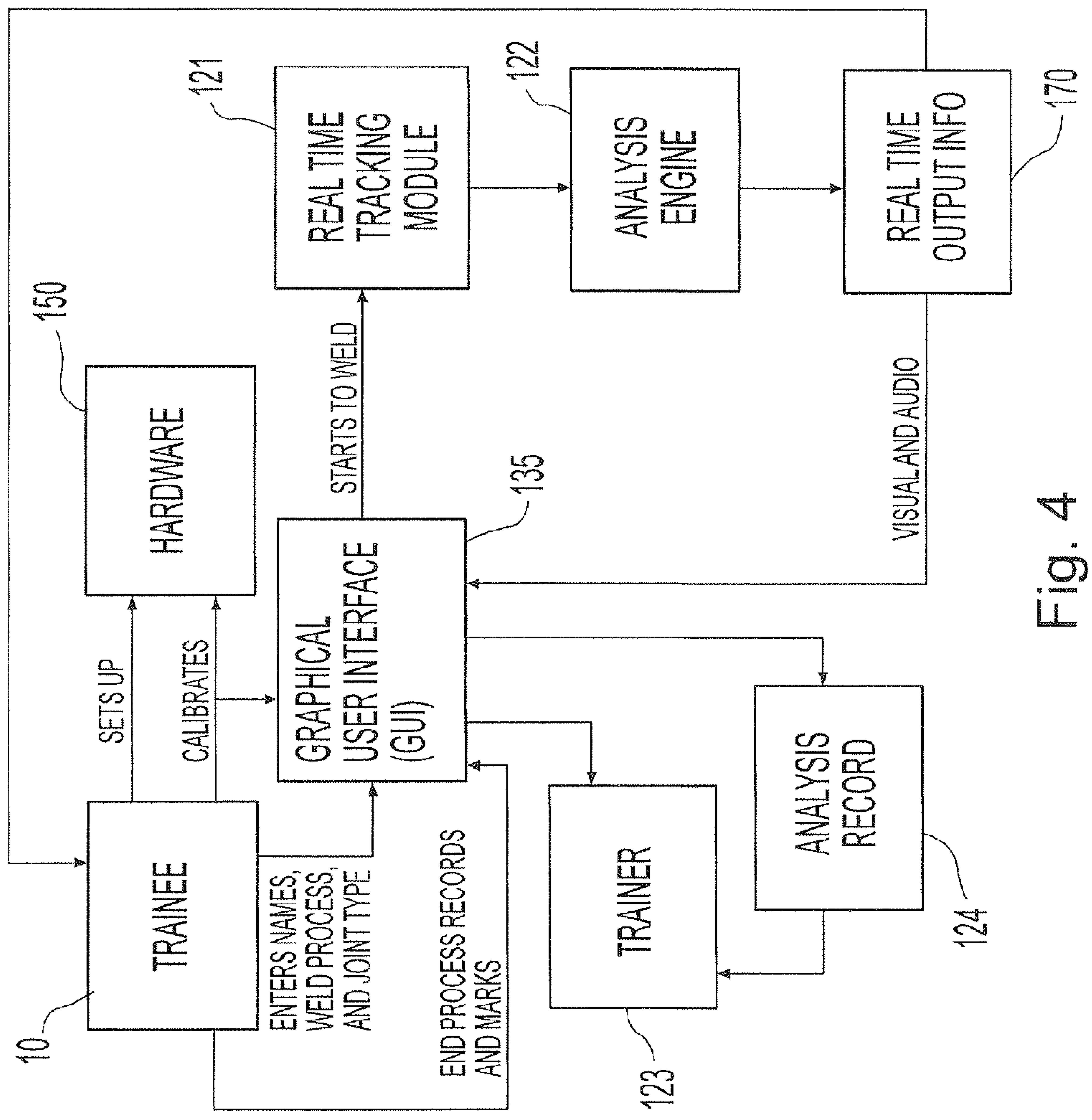

REAL TIME TRACKING MODULE
121
ANALYSIS ENGINE
122
REAL TIME OUTPUT INFO
170
HARDWARE
150
STARTS TO WELD
VISUAL AND AUDIO
GRAPHICAL USER INTERFACE (GUI)
135
SETS UP
CALIBRATES
TRAINEE
10
ENTERS NAMES, WELD PROCESS, AND JOINT TYPE
END PROCESS RECORDS AND MARKS
TRAINER
123
ANALYSIS RECORD
124

Fig. 4

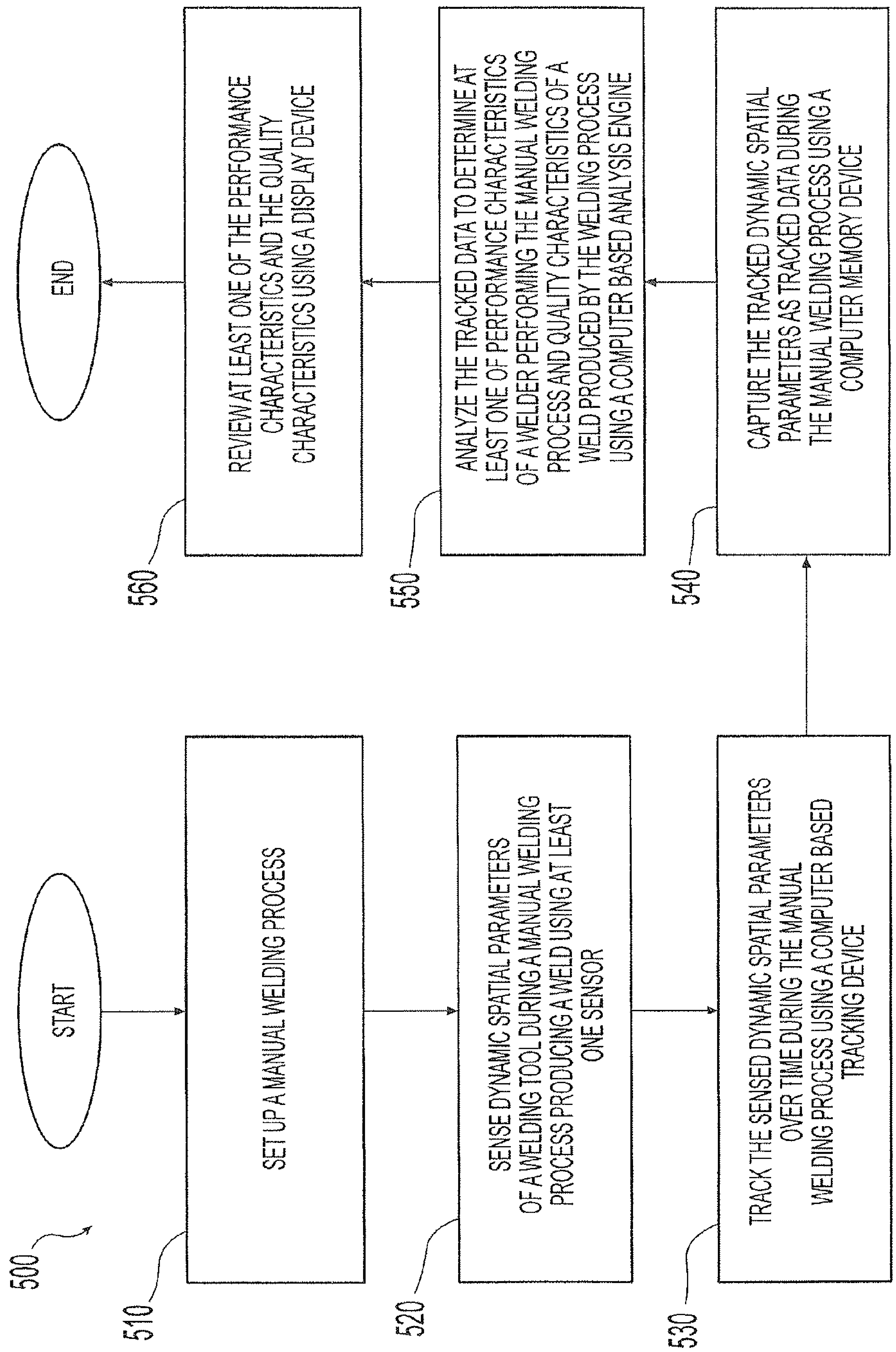
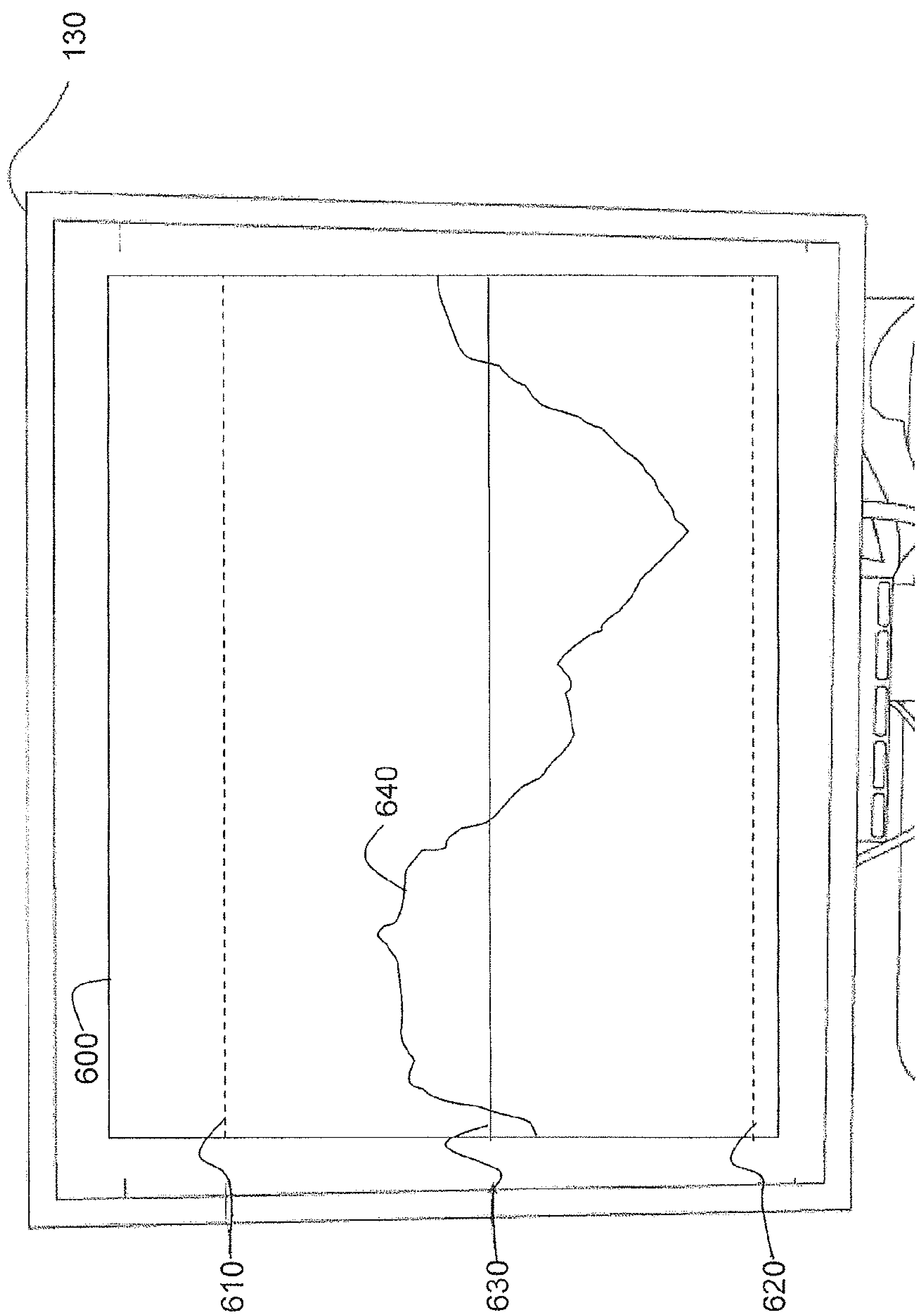

500
START
510
SET UP A MANUAL WELDING PROCESS
520
SENSE DYNAMIC SPATIAL PARAMETERS OF A WELDING TOOL DURING A MANUAL WELDING PROCESS PRODUCING A WELD USING AT LEAST ONE SENSOR
530
TRACK THE SENSED DYNAMIC SPATIAL PARAMETERS OVER TIME DURING THE MANUAL WELDING PROCESS USING A COMPUTER BASED TRACKING DEVICE
540
CAPTURE THE TRACKED DYNAMIC SPATIAL PARAMETERS AS TRACKED DATA DURING THE MANUAL WELDING PROCESS USING A COMPUTER MEMORY DEVICE
550
ANALYZE THE TRACKED DATA TO DETERMINE AT LEAST ONE OF PERFORMANCE CHARACTERISTICS OF A WELDER PERFORMING THE MANUAL WELDING PROCESS AND QUALITY CHARACTERISTICS OF A WELD PRODUCED BY THE WELDING PROCESS USING A COMPUTER BASED ANALYSIS ENGINE
560
REVIEW AT LEAST ONE OF THE PERFORMANCE CHARACTERISTICS AND THE QUALITY CHARACTERISTICS USING A DISPLAY DEVICE
END

Fig. 5

FIG. 6



SYSTEM FOR TRACKING AND ANALYZING WELDING ACTIVITY

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

This U.S. patent application claims priority to and the benefit of U.S. provisional patent application Ser. No. 61/158,578 which was filed on Mar. 9, 2009, and which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

Certain embodiments of the present invention pertain to systems for tracking and analyzing welding activity, and more particularly, to systems that capture weld data in real time (or near real time) for analysis and review. Additionally, the embodiments of the present invention provide a system for marking portions of a welded article by indicating possible discontinuities or flaws within the weld joint.

BACKGROUND

In many applications, ascertaining the quality of weld joints is critical to the use and operation of a machine or structure incorporating a welded article. In some instances, x-raying or other nondestructive testing is needed to identify potential flaws within one or more welded joints. However, non-destructive testing can be cumbersome to use, and typically lags the welding process until the inspector arrives to complete the testing. Additionally, it may not be effective for use with all weld joint configurations. Moreover, non-destructive testing does not provide any information about how the weld was completed. In welding applications where identifying waste is vital to producing cost effective parts, non-destructive testing provides no insight into problems like overfill.

Further limitations and disadvantages of conventional, traditional, and proposed approaches will become apparent to one of skill in the art, through comparison of such approaches with the subject matter of the present application as set forth in the remainder of the present application with reference to the drawings.

SUMMARY

The embodiments of the present invention pertain to a system for tracking and analyzing welding activity. The system may be used in conjunction with a welding power supply and includes a sensor array and logic processor-based technology that captures performance data (dynamic spatial properties) as the welder performs various welding activities. The system functions to evaluate the data via an analysis engine for determining weld quality in real time (or near real time). The system also functions to store and replay data for review at a time subsequent to the welding activity thereby allowing other users of the system to review the performance activity of the welding process.

These and other novel features of the subject matter of the present application, as well as details of illustrated embodiments thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a welder using an embodiment of a system for tracking and analyzing welding activity;

FIG. **2** is a schematic representation of an embodiment of the system of FIG. **1** for tracking and analyzing welding activity;

FIG. **3** is a schematic representation of an embodiment of the hardware and software of the system of FIGS. **1-2** for tracking and analyzing welding activity;

FIG. **4** is a flow diagram of an embodiment of the system of FIGS. **1-3** for tracking and analyzing welding activity;

FIG. **5** is a flowchart of an embodiment of a method for tracking and analyzing welding activity using the system of FIGS. **1-4**; and

FIG. **6** illustrates an example embodiment of a graph, displayed on a display, showing tracked welding tool pitch angle versus time with respect to an upper pitch angle limit, a lower pitch angle limit, and an ideal pitch angle.

DETAILED DESCRIPTION

FIG. **1** is a perspective view of a welder **10** using an embodiment of a system **100** for tracking and analyzing welding activity while performing a welding process with a welding system **200**. FIG. **2** is a schematic representation of an embodiment of the system **100** of FIG. **1** for tracking and analyzing welding activity. FIG. **3** is a schematic representation of an embodiment of the hardware **110**, **130** and software **120** of the system **100** of FIGS. **1-2** for tracking and analyzing welding activity. FIG. **4** is a flow diagram of an embodiment of the system **100** of FIGS. **1-3** for tracking and analyzing welding activity. FIG. **5** is a flowchart of an embodiment of a method **500** for tracking and analyzing welding activity using the system **100** of FIGS. **1-4**.

Referring again to the drawings wherein the showings are for purposes of illustrating embodiments of the invention only and not for purposes of limiting the same, FIG. **1** shows a system **100** for tracking and analyzing manual processes requiring the dexterity of a human end user **10**. In particular, system **100** functions to capture performance data related to the use and handling of tools (e.g., welding tools). In one embodiment, the system **100** is used to track and analyze welding activity, which may be a manual welding process in any of its forms including but not limited to: arc welding, laser welding, brazing, soldering, oxyacetylene and gas welding, and the like. For illustrative purposes, the embodiments of the present invention will be described in the context of arc welding. However, persons of ordinary skill in the art will understand its application to other manual processes. In accordance with alternative embodiments of the present invention, the manual welder **10** may be replaced with a robotic welder. As such, the performance of the robotic welder and resultant weld quality may be determined in a similar manner.

In one embodiment, the system **100** tracks movement or motion (i.e., position and orientation over time) of a welding tool **230**, which may be, for example, an electrode holder or a welding torch. Accordingly, the system **100** is used in conjunction with a welding system **200** including a welding power supply **210**, a welding torch **230**, and welding cables **240**, along with other welding equipment and accessories. As a welder **10**, i.e. end user **10**, performs welding activity in accordance with a welding process, the system **100** functions to capture performance data from real world welding activity as sensed by sensors **160**, **165** (see FIG. **2**) which are discussed in more detail later herein.

In accordance with an embodiment of the present invention, the system **100** for tracking and analyzing welding activity includes the capability to automatically sense dynamic spatial properties (e.g., positions, orientations, and movements) of a welding tool **230** during a manual welding process producing a weld **16** (e.g., a weld joint). The system **100** further includes the capability to automatically track the sensed dynamic spatial properties of the welding tool **230** over time and automatically capture (e.g., electronically capture) the tracked dynamic spatial properties of the welding tool **230** during the manual welding process.

The system **100** also includes the capability to automatically analyze the tracked data to determine performance characteristics of a welder **10** performing the manual welding process and quality characteristics of a weld **16** produced by the welding process. The system **100** allows for the performance characteristics of the welder **10** and the quality characteristics of the weld to be reviewed. The performance characteristics of a welder **10** may include, for example, a weld joint trajectory, a travel speed of the welding tool **230**, welding tool pitch and roll angles, an electrode distance to a center weld joint, an electrode trajectory, and a weld time. The quality characteristics of a weld produced by the welding process may include, for example, discontinuities and flaws within certain regions of a weld produced by the welding process.

The system **100** further allows a user (e.g., a welder **10**) to locally interact with the system **100**. In accordance with another embodiment of the present invention, the system **100** allows a remotely located user to remotely interact with the system **100**. In either scenario, the system **100** may automatically authorize access to a user of the system **100**, assuming such authorization is warranted.

In accordance with an embodiment of the present invention, the system **100** for tracking and analyzing welding activity includes a processor based computing device **110** configured to track and analyze dynamic spatial properties (e.g., positions, orientations, and movements) of a welding tool **230** over time during a manual welding process producing a weld **16**. The system **100** further includes at least one sensor array **160**, **165** operatively interfacing to the processor based computing device **110** (wired or wirelessly) and configured to sense the dynamic spatial properties of a welding tool **230** during a manual welding process producing a weld **16**. The system **100** also includes at least one user interface operatively interfacing to the processor based computing device **110**. The user interface may include a graphical user interface **135** and/or a display device (e.g., a display **130** or a welding display helmet **180** where a display is integrated into a welding helmet as illustrated in FIG. **2**). The system **100** may further include a network interface configured to interface the processor based computing device **110** to a communication network **300** (e.g., the internet).

In accordance with an embodiment of the present invention, a method **500** (see FIG. **5**) for tracking and analyzing welding activity includes, in step **510**, setting up a manual welding process, and, in step **520**, sensing dynamic spatial properties (e.g., positions, orientations, and movements) of a welding tool **230** during a manual welding process producing a weld using at least one sensor (e.g., sensor arrays **160** and **165**). In step **530**, the method includes tracking the sensed dynamic spatial properties over time during the manual welding process using a real time tracking module **121** (see FIG. **4**). The method also includes, in step **540**, capturing the tracked dynamic spatial properties as tracked data during the manual welding process using a computer based (e.g., electronic) memory device (e.g., a portion of the hardware **150** and software **120** of the processor based computing device **110**). The method further includes, in step **550**, analyzing the tracked data to determine performance characteristics of a welder **10** performing the manual welding process and/or quality characteristics of a weld produced by the welding process using a computer based analysis engine **122**. In step **560**, at least one of the performance characteristics and the quality characteristics are reviewed using a display device (e.g., display device **130**). Alternatively, a visualization module or a testing module may be used in place of the display device **130**, as are well known in the art.

The method **500** may initially include selecting welding set up parameters for the welding process via a user interface **135** as part of step **510**. The method may also include outputting the performance characteristics of the welder **10** and/or the quality characteristics of a weld to a remote location and remotely viewing the performance characteristics and/or the quality characteristics via a communication network **300** (see FIG. **3**).

The system **100** for tracking and analyzing welding activity comprises hardware and software components, in accordance with an embodiment of the present invention. In one embodiment, the system **100** incorporates electronic hardware. More specifically, system **100** may be constructed, at least in part, from electronic hardware **150** (see FIG. **4**) of the processor based computing device **110** operable to execute programmed algorithms, also referred to herein as software **120** or a computer program product. The processor based computing device **110** may employ one or more logic processors capable of being programmed, an example of which may include one or more microprocessors. However, other types of programmable circuitry may be used without departing from the intended scope of coverage of the embodiments of the present invention. In one embodiment, the processor based computing device **110** is operatively disposed as a microcomputer in any of various configurations including but not limited to: a laptop computer, a desktop computer, a work station, a server or the like. Alternatively, mini-computers or main frame computers may serve as the platform for implementing the system **100** for tracking and analyzing welding activity. Moreover, handheld or mobile processor based computing devices may be used to execute programmable code for tracking and analyzing performance data.

Other embodiments are contemplated wherein the system **100** is incorporated into the welding system **200**. More specifically, the components comprising the system **100** may be integrated into the welding power supply **210** and/or weld torch **230**. For example, the processor based computing device **110** may be received internal to the housing of the welding power supply **210** and may share a common power supply with other systems located therein. Additionally, sensors **160**, **165**, used to sense the weld torch **230** dynamic spatial properties, may be integrated into the weld torch handle.

The system **100** may communicate with and be used in conjunction with other similarly or dissimilarly constructed systems. Input to and output from the system **100**, termed I/O, may be facilitated by networking hardware and software including wireless as well as hard wired (directly connected) network interface devices. Communication to and from the system **100** may be accomplished remotely as through a network **300** (see FIG. **3**), such as, for example, a wide area network (WAN) or the Internet, or through a local area network (LAN) via network hubs, repeaters, or by any means chosen with sound engineering judgment. In this manner, information may be transmitted between systems as is useful for analyzing, and/or re-constructing and displaying performance and quality data.

In one embodiment, remote communications are used to provide virtual instruction by personnel, i.e. remote or offsite users, not located at the welding site. Reconstruction of the welding process is accomplished via networking. Data representing a particular weld may be sent to another similar or dissimilar system **100** capable of displaying the weld data (see FIG. **3**). It should be noted that the transmitted data is sufficiently detailed for allowing remote user(s) to analyze the welder's performance and the resultant weld quality. Data sent to a remote system **100** may be used to generate a virtual welding environment thereby recreating the welding process as viewed by offsite users as discussed later herein. Still, any way of communicating performance data to another entity remotely located from the welding site may be used without departing from the intended scope of coverage of the embodiments of the subject invention.

The processor based computing device **110** further includes support circuitry including electronic memory devices, along with other peripheral support circuitry that facilitate operation of the one or more logic processor(s), in accordance with an embodiment of the present invention. Additionally, the processor based computing device **110** may include data storage, examples of which include hard disk drives, optical storage devices and/or flash memory for the storage and retrieval of data. Still any type of support circuitry may be used with the one or more logic processors as chosen with sound engineering judgment. Accordingly, the processor based computing device **110** may be programmable and operable to execute coded instructions in a high or low level programming language. It should be noted that any form of programming or type of programming language may be used to code algorithms as executed by the system **100**.

With reference now to FIGS. **1-4**, the system **100** is accessible by the end user **10** via a display screen **130** operatively connected to the processor based computing device **110**. Software **120** installed onto the system **100** directs the end user's **10** interaction with the system **100** by displaying instructions and/or menu options on, for example, the display screen **130** via one or more graphical user interfaces (GUI) **135**. Interaction with the system **100** includes functions relating to, for example: part set up (weld joint set up), welding activity analysis, weld activity playback, real time tracking, as well as administrative activity for managing the captured data. Still other functions may be chosen as are appropriate for use with the embodiments of the present invention. System navigation screens, i.e. menu screens, may be included to assist the end user **10** in traversing through the system functions. It is noted that as the system **100** is used for training and analysis, security may be incorporated into the GUI(s) **135** that allow restricted access to various groups of end users **10**. Password security, biometrics, work card arrangement or other security measures may be used to ensure that system access is given only to authorized users as determined by an administrator or administrative user. It will be appreciated that the end user **10** may be the same or a different person than that of the administrative user.

In one embodiment, the system **100** functions to capture performance data of the end user **10** for manual activity as related to the use of tools or hand held devices. In the accompanying figures, welding, and more specifically, arc welding is illustrated as performed by the end user **10** on a weldment **15** (e.g., a weld coupon). The welding activity is recorded by the system **100** in real time or near-real time for tracking and analysis purposes mentioned above by a real time tracking module **121** and an analysis module **122**, respectively (see FIG. **4**). By recorded it is meant that the system **10** captures data related to a particular welding process for determining the quality of the weld joint or weld joints. The types of performance data that may be captured include, but are not limited to, for example: weld joint configuration or weld joint trajectory, weld speed, welding torch pitch and roll angles, electrode distance to the center weld joint, wire feed speed, electrode trajectory, weld time, and time and date data. Other types of data may also be captured and/or entered into the system **100** including: weldment materials, electrode materials, user name, project ID number, and the like. Still, any type and quantity of information may be captured and/or entered into the system **100** as is suitable for tracking, analyzing and managing weld performance data. In this manner, detailed information about how the welding process for a particular weld joint was performed may be captured and reconstructed for review and analysis in an analysis record **124**.

The data captured and entered into the system **100** is used to determine the quality of the real world weld joint. Persons of ordinary skill in the art will understand that a weld joint may be analyzed by various processes including destructive and non-destructive methods, examples of which include sawing/cutting or x-raying of the weld joint respectively. In prior art methods such as these, trained or experienced weld personnel can determine the quality of a weld performed on a weld joint. Of course, destructive testing renders the weldment unusable and thus can only be used for a sampling or a subset of welded parts. While non-destructive testing, like x-raying, do not destroy the welded article, these methods can be cumbersome to use and the equipment expensive to purchase. Moreover, some weld joints cannot be appropriately x-rayed, i.e. completely or thoroughly x-rayed. By way of contrast, system **100** captures performance data during the welding process that can be used to determine the quality of the welded joint. More specifically, system **100** is used to identify potential discontinuities and flaws within specific regions of a weld joint. The captured data may be analyzed by an experienced welder or trained professional (e.g., a trainer **123**, see FIG. **4**), or in an alternative by the system **100** using the analysis module **122** for identifying areas within the weld joint that may be flawed. In one example, torch position and orientation along with travel speed and other critical parameters are analyzed as a whole to predict which areas along the weld joint, if any, are deficient. It will be understood that quality is achieved during the welding process when the operator **10** keeps the weld torch **230** within acceptable operational ranges. Accordingly, the performance data may be analyzed against known good parameters for achieving weld quality for a particular weld joint configuration.

FIG. **6** illustrates an example embodiment of a graph **600**, displayed on the display **130**, showing tracked welding tool pitch angle **640** versus time with respect to an upper pitch angle limit **610**, a lower pitch angle limit **620**, and an ideal pitch angle **630**. The upper and lower limits **610** and **620** define a range of acceptability between them. Different limits may be predefined for different types of users such as, for example, welding novices, welding experts, and persons at a trade show. The analysis engine **122** may provide a scoring capability, in accordance with an embodiment of the present invention, where a numeric score is provided based on how close to optimum (ideal) a user is for a particular tracked parameter, and depending on the determined level of discontinuities or defects determined to be present in the weld.

Performance data may be stored electronically in a database **140** (see FIG. **3**) and managed by a database manager in a manner suitable for indexing and retrieving selected sets or subsets of data. In one embodiment, the data is retrieved and presented to an analyzing user (e.g., a trainer 123) for determining the weld quality of a particular weld joint. The data may be presented in tabular form for analysis by the analyzing user. Pictures, graphs, and or other symbol data may also be presented as is helpful to the analyzing user in determining weld quality. In an alternative embodiment, the performance data may be presented to the analyzing user in a virtual reality setting, whereby the real world welding process is simulated using real world data as captured by the system 100. An example of such a virtual reality setting is discussed in U.S. patent application Ser. No. 12/501,257 filed on Jul. 10, 2009. In this way, the weld joint and corresponding welding process may be reconstructed for review and analysis. Accordingly, the system 100 may be used to archive real data as it relates to a particular welded article. Still, it will be construed that any manner of representing captured data or reconstructing the welding process for the analyzing user may be used as is appropriate for determining weld quality.

In another embodiment, data captured and stored in the database 140 is analyzed by an analyzing module 122 (a.k.a., an analysis engine) of the system 100. The analyzing module 122 may comprise a computer program product executed by the processor based computing device 110. The computer program product may use artificial intelligence. In one particular embodiment, an expert system may be programmed with data derived from a knowledge expert and stored within an inference engine for independently analyzing and identifying flaws within the weld joint. By independently, it is meant that the analyzing module 122 functions independently from the analyzing user to determine weld quality. The expert system may be ruled-based and/or may incorporate fuzzy logic to analyze the weld joint. In this manner, areas along the weld joint may be identified as defective, or potentially defective, and marked for subsequent review by an analyzing user. Determining weld quality and/or problem areas within the weld joint may be accomplished by heuristic methods. As the system 100 analyzes welding processes of the various end users over repeated analyzing cycles, additional knowledge may be gained by the system 100 for determining weld quality.

A neural network or networks may be incorporated into the analysis engine 122 of the system 100 for analyzing data to determine weld quality, weld efficiency and/or weld flaws or problems. Neural networks may comprise software programming that simulates decision making capabilities. In one embodiment, the neural network(s) may process data captured by the system 100 making decisions based on weighted factors. It is noted that the neural network(s) may be trained to recognize problems that may arise from the weld torch position and movement, as well as other critical welding factors. Therefore, as data from the welding process is captured and stored, the system 100 may analyze the data for identifying the quality of the weld joint. Additionally, the system 100 may provide an output device 170 (see FIG. 4) that outputs indications of potential flaws in the weld such as, for example, porosity, weld overfill, and the like.

In capturing performance data, the system 100 incorporates a series of sensors, also referred to as sensor arrays 160, 165 (see FIG. 2). The sensor arrays 160, 165 include emitters and receivers positioned at various locations in proximity to the weldment 15, and more specifically, in proximity to the weld joint 16 for determining the position and orientation of the weld torch 230 in real time (or near real time). In one embodiment, the sensor arrays 160, 165 include acoustical sensor elements. It is noted that the acoustical sensor elements may use waves in the sub-sonic and/or ultra-sonic range. Alternate embodiments are contemplated that use optical sensor elements, infrared sensor elements, laser sensor elements, magnetic sensor elements, or electromagnetic (radio frequency) sensor elements. In this manner, the sensor emitter elements emit waves of energy in any of various forms that are picked up by the sensor receiver elements. To compensate for noise introduced by the welding process, the system 100 may also include bandwidth suppressors, which may be implemented in the form of software and/or electronic circuitry. The bandwidth suppressors are used to condition the sensor signals to penetrate interference caused by the welding arc. Additionally, the system 100 may further incorporate inertial sensors, which may include one or more accelerometers. In this manner, data relating to position, orientation, velocity, and acceleration may be required to ascertain the movements (i.e., motion) of the weld torch 230.

In one embodiment, part of the sensor arrays 160, 165 are received by the weld torch 230. That is to say that a portion of the sensors or sensor elements are affixed with respect to the body of the weld torch 230 (see sensor array **[160]** *165* of FIG. 2). In other embodiments, sensors and/or sensor elements may be affixed to a portion of the article being welded (see sensor array **[165]** *160* of FIG. 2). Still any manner of positioning and connecting the sensor elements may be chosen as is appropriate for tracking welding activity.

As an example of sensing and tracking a welding tool 230, in accordance with an embodiment of the present invention, a magnetic sensing capability may be provided. For example, the receiver sensor array 165 may be a magnetic sensor that is mounted on the welding tool 230, and the emitter sensor array 160 may take the form of a magnetic source. The magnetic source 160 may be mounted in a predefined fixed position and orientation with respect to the weldment 15. The magnetic source 160 creates a magnetic field around itself, including the space encompassing the welding tool 230 during use and establishes a 3D spatial frame of reference. The magnetic sensor 165 is provided which is capable of sensing the magnetic field produced by the magnetic source. The magnetic sensor 165 is attached to the welding tool 230 and is operatively connected to the processor based computing device 110 via, for example, a cable, or wirelessly. The magnetic sensor 165 includes an array of three induction coils orthogonally aligned along three spatial directions. The induction coils of the magnetic sensor 165 each measure the strength of the magnetic field in each of the three directions and provide that information to the real time tracking module 121 of the processor based computing device 110. As a result, the system 100 is able to know where the welding tool 230 is in space with respect to the 3D spatial frame of reference established by the magnetic field produced by the magnetic source 160. In accordance with other embodiments of the present invention, two or more magnetic sensors may be mounted on or within the welding tool 230 to provide a more accurate representation of the position and orientation of the welding tool 230, for example. Care is to be taken in establishing the magnetic 3D spatial frame of reference such that the weldment 15, the tool 230, and any other portions of the welding environment do not substantially distort the magnetic field created by the magnetic source 160. As an alternative, such distortions may be corrected for or calibrated out as part of a welding environment set up procedure. Other non-magnetic technologies (e.g., acoustic, optical, electromagnetic, inertial, etc.) may be used, as previously discussed herein, to avoid such distortions, as are well known in the art.

With reference to all of the figures, operation of the system 100 will now be described in accordance with an embodiment of the present invention. The end user 10 activates the system

100 and enters his or her user name via the user interface **135**. Once authorized access has been gained, the end user **10** traverses the menu system as prompted by the computer program product **120** via the GUI **135**. The system **100** instructs the end user **10** to initiate set up of the welding article **15**, which includes entering information about the weldment materials and/or welding process being used. Entering such information may include, for example, selecting a language, entering a user name, selecting a weld coupon type, selecting a welding process and associated axial spray, pulse, or short arc methods, selecting a gas type and flow rate, selecting a type of stick electrode, and selecting a type of flux cored wire.

In one embodiment, the end user enters the starting and ending points of the weld joint **16**. This allows the system **100**, via the real time tracking module **121**, to determine when to start and stop recording the tracked information. Intermediate points are subsequently entered for interpolating the weld joint trajectory as calculated by the system **100**. Additionally, sensor emitters and/or receivers **160**, **165** are placed proximate to the weld joint at locations suitable for gathering data in a manner consistent with that described herein. After set up is completed, system tracking is initiated and the end user **10** is prompted to begin the welding procedure. As the end user **10** completes the weld, the system **100** gathers performance data including the speed, position and orientation of the weld torch **230** for analysis by the system **100** in determining welder performance characteristics and weld quality characteristics as previously described herein.

In summary, a system and a method for tracking and analyzing welding activity is disclosed. Dynamic spatial properties of a welding tool are sensed during a welding process producing a weld. The sensed dynamic spatial properties are tracked over time and the tracked dynamic spatial properties are captured as tracked data during the welding process. The tracked data is analyzed to determine performance characteristics of a welder performing the welding process and quality characteristics of a weld produced by the welding process. The performance characteristics and the quality characteristics may be subsequently reviewed.

While the claimed subject matter of the present application has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the claimed subject matter. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the claimed subject matter without departing from its scope. Therefore, it is intended that the claimed subject matter not be limited to the particular embodiment disclosed, but that the claimed subject matter will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A system for tracking and analyzing welding activity, said system comprising:

means for automatically sensing [dynamic] spatial properties of a welding tool during a welding process producing a *real world* weld;

means for automatically tracking said sensed [dynamic] spatial properties [over time] during said welding process;

means for automatically capturing *in real time or near real time* said tracked dynamic spatial properties as tracked data during said welding process; and

means for automatically analyzing *in real time or near real time* said tracked data to determine [at least one of performance characteristics of a welder performing said welding process and] *a* quality [characteristics] *characteristic* of [a] *said real world* weld produced by said welding process.

2. The system of claim **1**, *wherein said analyzing further comprises determining a performance characteristic of a welder performing said welding process, and*

said system further [comprising] *comprises* means for reviewing said performance [characteristics] *characteristic* of [a] *said* welder performing said welding process.

3. The system of claim **1** further comprising means for reviewing said quality [characteristics] *characteristic* of [a] *said real world* weld produced by said welding process.

4. The system of claim **1** further comprising means for a user to locally interact with said system.

5. The system of claim **1** further comprising means for a user to remotely interact with said system.

6. The system of claim **1** further comprising means for automatically authorizing access to a user of said system.

7. The system of claim **1**, *wherein said analyzing comprises determining a performance characteristic of a welder performing said welding process, and*

wherein said performance [characteristics of a welder include] *characteristic includes* at least one of a weld joint trajectory, a travel speed of said welding tool, welding tool pitch and roll angles, an electrode distance to a center weld joint, an electrode trajectory, and a weld time.

8. The system of claim **1** wherein said quality [characteristics of a weld produced by said welding process include] *characteristic includes* at least one of discontinuities and flaws within regions of [a] *said real world* weld produced by said welding process.

9. A system for tracking and analyzing welding activity, said system comprising:

at least one sensor array configured to sense [dynamic] spatial properties of a welding tool during a welding process producing a *real world* weld;

a processor based computing device operatively interfacing to said at least one sensor array and configured to track and analyze *in real time or near real time* said [dynamic] spatial properties of [a] *said* welding tool [over time] during [a] *said* welding process producing [a] *said real world* weld; and

at least one user interface operatively interfacing to said processor based computing device*, said at least one user interface displaying a quality characteristic of said real world weld produced by said welding process*.

10. The system of claim **9** wherein said at least one user interface includes a graphical user interface.

11. The system of claim **9** wherein said at least one user interface includes a display device.

12. The system of claim **9** further comprising a network interface configured to interface said processor based computing device to an external communication network.

13. The system of claim **9** wherein said at least one sensor array includes at least one of acoustical sensor elements, optical sensor elements, magnetic sensor elements, *inertial sensor elements,* and electromagnetic sensor elements.

14. A method for tracking and analyzing welding activity, said method comprising:

sensing [dynamic] spatial properties of a welding tool during a welding process producing a *real world* weld [using at least one sensor];

tracking said sensed [dynamic] spatial properties [over time] *in real time or near real time* during said welding process [using a real time tracking module];

capturing said tracked [dynamic] spatial properties as tracked data *in real time or near real time* during said welding process [using a computer based memory device]; and

analyzing said tracked data *in real time or near real time* to determine [at least one of performance characteristics of a welder performing said welding process and] *a* quality [characteristics] *characteristic* of [a] *said real world* weld produced by said welding process [using a computer based analysis engine].

15. The method of claim **14**, *wherein said analyzing further comprises determining a performance characteristic of a welder performing said welding process, and*

wherein said method further [comprising] *comprises* outputting said performance [characteristics] *characteristic* of [a] *said* welder performing said welding process to at least one of a display device, a visualization module, and a testing module for review.

16. The method of claim **14** further comprising outputting said quality [characteristics] *characteristic* of [a] *said real world* weld produced by said welding process to at least one of a display device, a visualization module, and a testing module for review.

17. The method of claim **14** further comprising selecting welding set up parameters for said welding process via a user interface.

18. The method of claim [**14**] *15* further comprising remotely reviewing at least one of said performance [characteristics] *characteristic* of [a] *said* welder performing said welding process and said quality [characteristics] *characteristic* of [a] *said real world* weld produced by said welding process, via a communication network.

19. The method of claim **14**, *wherein said analyzing further comprises determining a performance characteristic of a welder performing said welding process, and*

wherein said performance [characteristics of a welder include] *characteristic includes* at least one of a weld joint trajectory, a travel speed of said welding tool, welding tool pitch and roll angles, an electrode distance to a center weld joint, an electrode trajectory, and a weld time.

20. The method of claim **14** wherein said quality [characteristics of a weld produced by said welding process include] *characteristic includes* at least one of discontinuities and flaws within regions of [a] *said real world* weld produced by said welding process.

21. The system of claim 9, wherein said analysis of said spatial properties comprise determining at least one of a performance characteristic of a welder performing said welding process and a quality characteristic of said real world weld.

22. The system of claim 21, wherein said performance characteristic includes at least one of a weld joint trajectory, a travel speed of said welding tool, welding tool pitch and roll angles, an electrode distance to a center weld joint, an electrode trajectory, and a weld time.

23. The system of claim 21, wherein said quality characteristic includes at least one of a discontinuity and a flaw within a region of said weld produced by said welding process.

24. The system of claim 23, wherein said quality characteristic includes said flaw and said flaw comprises at least one of porosity and weld overfill.

25. The system of claim 24, wherein said spatial properties comprise at least one of a position, an orientation, and a movement of said welding tool.

26. The system of claim 9, wherein said welding tool comprises a portion of said at least one sensor array.

27. The system of claim 26, wherein said portion of said at least one sensor array includes at least one of acoustical sensor elements, magnetic sensor elements, inertial sensor elements, and electromagnetic sensor elements.

28. The system of claim 12, wherein said network interface is configured to transmit data representing said welding process to a remote system.

29. The system of claim 28, wherein said transmitted data comprises information related to a welder's performance.

30. The system of claim 9, wherein said processor based computing device is further configured to record in real time or near real time performance data corresponding to said welding process, and

wherein said performance data comprises at least one of a weld joint configuration or a weld joint trajectory, a weld speed, welding tool pitch and roll angles, an electrode distance to a center weld joint, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

31. The system of claim 30, wherein said processor based computing device is further configured to record at least one of weldment materials, electrode materials, user name, and project ID number.

32. The system of claim 31, wherein said analyzing further comprises comparing said performance data to known parameters to determine said quality characteristic of said real world weld.

33. The system of claim 9, wherein said analyzing comprises determining a score based on a comparison of at least one of said tracked spatial properties to an optimum value corresponding to said at least one of said tracked spatial properties.

34. The system of claim 33, wherein said optimum value is a range comprising an upper limit and a lower limit for said at least one of said tracked spatial properties.

35. The system of claim 34, wherein said tracked spatial properties comprise at least one of a weld joint trajectory, a weld speed, welding tool pitch angle, welding tool roll angle, an electrode distance to a center weld joint, a wire feed speed, and an electrode trajectory.

36. The system of claim 35, wherein said tracked spatial properties includes said welding tool pitch angle.

37. The system of claim 9, wherein said welding process is performed manually.

38. The system of claim 9, wherein said welding process is performed by a robotic welder.

39. The system of claim 11, wherein said display device is integrated into a welding helmet.

40. The system of claim 9, wherein said processor based computing device is configured to set up a virtual reality setting in which said welding process can be simulated using said spatial properties of said welding tool.

41. The system of claim 9, wherein said welding tool is one of an electrode holder and a welding torch.

42. The system of claim 9, wherein said analysis is performed by an expert system configured identify defective or potentially defective areas along a weld joint.

43. The system of claim 42, wherein said expert system comprises at least one of a rule-based system and a neural network.

44. The system of claim 43, wherein said expert system is said neural network and said analysis is based on weighted factors.

45. The system of claim 9, wherein said processor based computing device is further configured to capture information corresponding to said welding process in an analysis record for subsequent review.

46. The method of claim 14, wherein said sensing comprises measuring at least one of an acoustical signal, a magnetic signal, an optical signal, inertial signal, and an electromagnetic signal.

47. The method of claim 14, further comprising transmitting to a remote system data representing said welding process.

48. The method of claim 47, further comprising analyzing said welding process based on said transmitted data.

49. The method of claim 14, further comprising recording in real time or near real time performance data corresponding to said welding process,

wherein said performance data comprises at least one of a weld joint configuration or a weld joint trajectory, a weld speed, welding tool pitch and roll angles, an electrode distance to a center weld joint, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

50. The method of claim 49, wherein said recording further comprises recording data corresponding to at least one of weldment materials, electrode materials, user name, and project ID number.

51. The method of claim 49, wherein said analyzing comprises comparing said performance data to known parameters to determine said quality characteristic of said real world weld.

52. The method of claim 14, wherein said analyzing comprises determining a score based on a comparison of at least one of said tracked spatial properties to an optimum value.

53. The method of claim 52, wherein said optimum value is a range comprising an upper limit and a lower limit for said at least one of said tracked spatial properties.

54. The method of claim 53, wherein said tracked spatial properties comprise at least one of a weld joint trajectory, a weld speed, welding tool pitch angle, welding tool roll angle, an electrode distance to a center weld joint, a wire feed speed, and an electrode trajectory.

55. The system of claim 54, wherein said tracked spatial properties includes said welding tool pitch angle.

56. The method of claim 14, wherein said welding process is performed manually.

57. The method of claim 14, wherein said welding process is performed by a robotic welder.

58. The method of claim 14, further comprising storing information on said welding process an analysis record.

59. The method of claim 15, wherein said display device is integrated into a welding helmet.

60. The method of claim 16, wherein said display device is integrated into a welding helmet.

61. The method of claim 14, further comprising setting up a virtual reality setting in which said welding process can be simulated using said spatial properties of said welding tool.

62. The method of claim 14, wherein said welding tool is one of an electrode holder and a welding torch.

63. The method of claim 14, further comprising using an expert system to identify defective or potentially defective areas along said weld.

64. The method of claim 63, wherein said expert system uses at least one of a rule-based system and a neural network.

65. The method of claim 64, wherein said expert system uses said neural network and said identification is based on weighted factors.

66. The method of claim 14, further comprising capturing information corresponding to said welding process in an analysis record for subsequent review.

67. The method of claim 20, wherein said flaws comprise at least one of porosity and weld overfill.

68. The method of claim 67, wherein said spatial properties comprise at least one of a position, an orientation, and a movement of said welding tool.

69. A system for tracking and analyzing welding activity, said system comprising:

at least one sensor array configured to sense spatial properties of a welding tool during a welding process producing a real world weld; and

a processor based computing device operatively interfacing to said at least one sensor array and configured to track said spatial properties and record performance data corresponding to said welding process, said processor based computing device further configured to determine a quality characteristic of said real world weld.

70. The system of claim 69, wherein said analysis comprises comparing said performance data to known parameters to determine said quality characteristic of said weld.

71. The system of claim 70, wherein said quality characteristic includes at least one of a discontinuity and a flaw within a region of said weld.

72. The system of claim 71, wherein said recording is performed in real time or near real time.

73. The system of claim 72, wherein said spatial properties comprise at least one of a position, an orientation, and a movement of said welding tool, and

wherein said performance data comprises at least one of a weld joint configuration or a weld joint trajectory, a weld speed, welding tool pitch and roll angles, an electrode distance to a center weld joint, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

74. The system of claim 73, wherein said processor based computing device is further configured to record at least one of weldment materials, electrode materials, user name, and project ID number.

75. The system of claim 73, wherein said analyzing further comprises determining a score based on at least a comparison of at least one of said tracked spatial properties to an optimum value said at least one of said tracked spatial properties.

76. The system of claim 75, wherein said optimum value is a range comprising an upper limit and a lower limit for said at least one of said tracked spatial properties.

77. The system of claim 76, wherein said tracked spatial properties comprise at least one of a weld joint trajectory, a weld speed, welding tool pitch angle, welding tool roll angle, an electrode distance to a center weld joint, a wire feed speed, and an electrode trajectory.

78. The system of claim 77, wherein said tracked spatial properties includes said welding tool pitch angle.

79. The system of claim 71, wherein said quality characteristic includes said flaw and said flaw comprises at least one of porosity and weld overfill.

80. The system of claim 69, wherein said welding process is performed manually.

81. The system of claim 69, wherein said welding process is performed by a robotic welder.

82. The system of claim 69, further comprising a display device to display said quality characteristic.

83. The system of claim 82, wherein said display device is integrated into a welding helmet.

84. The system of claim 69, wherein said processor based computing device is configured to set up a virtual reality setting in which said welding process can be simulated using said spatial properties of said welding tool.

85. The system of claim 69, wherein said welding tool is one of an electrode holder and a welding torch.

86. The system of claim 69, wherein said analysis is performed by an expert system configured identify defective or potentially defective areas along said weld.

87. The system of claim 86, wherein said expert system is a neural network and said analysis is based on weighted factors.

88. The system of claim 69, wherein said processor based computing device is further configured to capture information corresponding to said welding process in an analysis record for subsequent review.

89. A system for tracking and analyzing welding activity, said system comprising:

a tracking module configured to track spatial positions of a welding tool during a welding process; and

a processor subsystem configured to ascertain at least one welding parameter during the welding process based on said tracked spatial positions and to determine a score based on a comparison of said at least one welding parameter to an optimum value.

90. The system of claim 89, wherein said at least one welding parameter includes a performance characteristic of a welder.

91. The system of claim 89, wherein said at least one welding parameter includes a quality characteristic of a weld.

92. The system of claim 89, wherein said at least one welding parameter includes a performance characteristic of a welder and a quality characteristic of a weld.

93. The system of claim 89, wherein said processor subsystem includes an expert system.

94. The system of claim 93, wherein said expert system comprises at least one of a rule-based system and a neural network.

95. The system of claim 89, wherein said optimum value is a range comprising an upper limit and a lower limit for said at least one welding parameter.

96. The system of claim 95, wherein said at least one welding parameter comprises at least one of a weld joint trajectory, a weld speed, welding tool pitch angle, welding tool roll angle, an electrode distance to a center weld joint, a wire feed speed, and an electrode trajectory.

97. The system of claim 96, wherein said tracked spatial properties includes said welding tool pitch angle.

98. The system of claim 97, wherein said welding process is performed manually.

99. The system of claim 89, wherein said welding process is performed by a robotic welder.

100. The system of claim 91, further comprising a display device to display said quality characteristic.

101. The system of claim 100, wherein said display is integrated into a welding helmet.

102. The system of claim 89, wherein said processor based computing device is configured to set up a virtual reality setting in which said welding process can be simulated using said spatial properties of said welding tool.

103. The system of claim 89, wherein said welding tool is one of an electrode holder and a welding torch.

104. A method for tracking and analyzing welding activity, said method comprising:

sensing spatial properties of a welding tool during a welding process producing a real world weld;

tracking said sensed spatial properties;

recording performance data corresponding to said welding process; and

analyzing said performance data in real-time or near real-time to determine a quality characteristic of said real world weld produced by said welding process.

105. The method of claim 104, wherein said analyzing comprises comparing said performance data to a known parameter to determine said quality characteristic of said real world weld.

106. The method of claim 105, wherein said welding process is performed by a robotic welder.

107. The method of claim 105, wherein said quality characteristic includes at least one of a discontinuity and a flaw within a region of said real world weld.

108. The method of claim 107, wherein said quality characteristic includes said flaw and said flaw comprises at least one of porosity and weld overfill.

109. The method of claim 107, wherein said recording is performed in real time or near real time.

110. The method of claim 109, wherein said spatial properties comprise at least one of a position, an orientation, and a movement of said welding tool, and

wherein said performance data comprises at least one of a weld joint configuration or a weld joint trajectory, a weld speed, welding tool pitch and roll angles, an electrode distance to a center weld joint, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

111. The method of claim 110, wherein further comprising recording at least one of weldment materials, electrode materials, user name, and project ID number.

112. The method of claim 104, wherein said analyzing further comprises determining a score based on at least a comparison of at least one of said tracked spatial properties to an optimum value.

113. The method of claim 112, wherein said optimum value is a range comprising an upper limit and a lower limit for said at least one of said tracked spatial properties.

114. The method of claim 113, wherein said tracked spatial properties comprise at least one of a weld joint trajectory, a weld speed, welding tool pitch angle, welding tool roll angle, an electrode distance to a center weld joint, a wire feed speed, and an electrode trajectory.

115. The system of claim 114, wherein said tracked spatial properties includes said welding tool pitch angle.

116. The method of claim 104, wherein said welding process is performed manually.

117. The method of claim 104, further comprising outputting said quality characteristic to a display device.

118. The method of claim 117, wherein said display device is integrated into a welding helmet.

119. The method of claim 104, further comprising setting up a virtual reality setting in which said welding process can be simulated using said spatial properties of said welding tool.

120. The method of claim 104, wherein said welding tool is one of an electrode holder and a welding torch.

121. The method of claim 104, further comprising using an expert system to identify defective or potentially defective areas along said weld.

122. The method of claim 121, wherein said expert system is a neural network and said identification is based on weighted factors.

123. The method of claim 104, further comprising capturing information corresponding to said welding process in an analysis record for subsequent review.

124. A method for tracking and analyzing welding activity, said system comprising:

tracking spatial positions of a welding tool during a welding process;

determining at least one welding parameter during the welding process based on said tracked spatial positions;

determining a score based on a comparison of said at least one welding parameter to an optimum value.

125. The method of claim 124, wherein said determining of said at least one welding parameter comprises analyzing a performance characteristic of a welder.

126. The method of claim 124, wherein said determining of said at least one welding parameter comprises analyzing a quality characteristic of a weld.

127. The method of claim 124, wherein said determining of said at least one welding parameter comprises analyzing a performance characteristic of a welder and a quality characteristic of a weld.

128. The method of claim 124, wherein said determining of said at least one welding parameter comprises using an expert system.

129. The method of claim 128, wherein said expert system uses at least one of a rule-based system and a neural network.

130. The method of claim 124, wherein said optimum value is a range comprising an upper limit and a lower limit for said at least one welding parameter.

131. The method of claim 130, wherein said at least one welding parameter comprises at least one of a weld joint trajectory, a weld speed, welding tool pitch angle, welding tool roll angle, an electrode distance to a center weld joint, a wire feed speed, and an electrode trajectory.

132. The method of claim 131, wherein said at least one welding parameter includes said welding tool pitch angle.

133. The method of claim 124, wherein said welding process is performed manually.

134. The method of claim 124, wherein said welding process is performed by a robotic welder.

135. The method of claim 124, further comprising setting up a virtual reality setting in which said welding process can be simulated using said spatial properties of said welding tool.

136. The system of claim 124, wherein said welding tool is one of an electrode holder and a welding torch.

137. A system for tracking welding activity, said system comprising:

an optical tracking system that tracks at least one of a position, a movement, and an orientation of a welding tool; and

a computer operatively interfacing to said optical tracking system, said computer determining at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool,

wherein said processor based computing device determines for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter.

138. The system of claim 137, wherein said score relates to a weld quality of a real world weld.

139. The system of claim 138, wherein said score relates to said weld quality of said real world weld, and

wherein said weld quality includes an indication of at least one of a discontinuity and a flaw within a region of said real world weld.

140. The system of claim 139, wherein said weld quality includes an indication of said flaw and said flaw comprises at least one of porosity and weld overfill.

141. The system of claim 139, wherein said determination of said score is performed in real time or near real time.

142. The system of claim 138, wherein an expert system identifies defective or potentially defective areas along said real world weld.

143. The system of claim 137, wherein said at least one parameter further includes at least one of a weld joint configuration or a weld joint trajectory, a weld speed, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

144. The system of claim 137, wherein said processor based computing device is further configured to record at least one of weldment materials, electrode materials, user name, and project ID number.

145. The system of claim 137, wherein said at least one predetermined limit includes an upper limit and a lower limit.

146. The system of claim 137, further comprising a display device to display said score.

147. The system of claim 146, wherein said display device is integrated into a welding helmet.

148. The system of claim 137, wherein said welding tool is one of an electrode holder and a welding torch.

149. A system for tracking welding activity, said system comprising:

an infrared tracking system that tracks at least one of a position, a movement, and an orientation of a welding tool based on an infrared element attached to said welding tool; and

a computer operatively interfacing to said infrared tracking system, said computer determining at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool,

wherein said computer determines for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter.

150. The system of claim 149, wherein said score relates to a weld quality of a real world weld.

151. The system of claim 150, wherein an expert system identifies defective or potentially defective areas along said real world weld.

152. The system of claim 150, wherein said score relates to said weld quality of said real world weld, and

wherein said weld quality includes an indication of at least one of a discontinuity and a flaw within a region of said real world weld.

153. The system of claim 152, wherein said weld quality includes an indication of said flaw and said flaw comprises at least one of porosity and weld overfill.

154. The system of claim 152, wherein said determination of said score is performed in real time or near real time.

155. The system of claim 149, wherein said at least one parameter further includes at least one of a weld joint configuration or a weld joint trajectory, a weld speed, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

156. The system of claim 149, wherein said processor based computing device is further configured to record at least one of weldment materials, electrode materials, user name, and project ID number.

157. The system of claim 149, wherein said at least one predetermined limit includes an upper limit and a lower limit.

158. The system of claim 149, further comprising a display device to display said score.

159. The system of claim 158, wherein said display device is integrated into a welding helmet.

160. The system of claim 149, wherein said welding tool is one of an electrode holder and a welding torch.

161. A method for tracking welding activity, said method comprising:

optically tracking at least one of a position, a movement, and an orientation of a welding tool;

determining at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool; and

computing for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter.

162. The method of claim 161, wherein said score relates to a weld quality of a real world weld.

163. The method of claim 162, wherein an expert system identifies defective or potentially defective areas along said real world weld.

164. The method of claim 162, wherein said score relates to said weld quality of said real world weld, and

wherein said weld quality includes an indication of at least one of a discontinuity and a flaw within a region of said real world weld.

165. The method of claim 164, wherein said weld quality includes an indication of said flaw and said flaw comprises at least one of porosity and weld overfill.

166. The method of claim 164, wherein said determination of said score is performed in real time or near real time.

167. The method of claim 161, wherein said at least one parameter further includes at least one of a weld joint configuration or a weld joint trajectory, a weld speed, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

168. The method of claim 167, wherein said processor based computing device is further configured to record at least one of weldment materials, electrode materials, user name, and project ID number.

169. The method of claim 161, wherein said at least one predetermined limit includes an upper limit and a lower limit.

170. The method of claim 161, further comprising a display device to display said score.

171. The method of claim 170, wherein said display device is integrated into a welding helmet.

172. The method of claim 161, wherein said welding tool is one of an electrode holder and a welding torch.

173. A method for tracking welding activity, said method comprising:

tracking by infrared at least one of a position, a movement, and an orientation of a welding tool based on an infrared element attached to said welding tool;

determining at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool; and

computing for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter.

174. The method of claim 173, wherein said score relates to a weld quality of a real world weld.

175. The method of claim 174, wherein said score relates to said weld quality of said real world weld, and

wherein said weld quality includes an indication of at least one of a discontinuity and a flaw within a region of said real world weld.

176. The method of claim 175, wherein said weld quality includes an indication of said flaw and said flaw comprises at least one of porosity and weld overfill.

177. The method of claim 175, wherein said determination of said score is performed in real time or near real time.

178. The method of claim 174, wherein an expert system identifies defective or potentially defective areas along said real world weld.

179. The method of claim 173, wherein said at least one parameter further includes at least one of a weld joint configuration or a weld joint trajectory, a weld speed, a wire feed speed, an electrode trajectory, a weld time, and time and date data.

180. The method of claim 179, wherein said processor based computing device is further configured to record at least one of weldment materials, electrode materials, user name, and project ID number.

181. The method of claim 173, wherein said at least one predetermined limit includes an upper limit and a lower limit.

182. The method of claim 173, further comprising a display device to display said score.

183. The method of claim 182, wherein said display device is integrated into a welding helmet.

184. The method of claim 173, wherein said welding tool is one of an electrode holder and a welding torch.

185. A system for tracking and analyzing welding activity, said system comprising:

at least one sensor array configured to sense spatial properties of a welding tool during a welding process producing a real world weld;

a processor based computing device operatively interfacing to said at least one sensor array and configured to track and analyze in real time or near real time said spatial properties of said welding tool during said welding process producing said real world weld; and

at least one display interfacing to said processor based computing device, said at least one display displaying a quality characteristic of said real world weld produced by said welding process.

186. A system for tracking welding activity, said system comprising:

an infrared tracking system that tracks at least one of a position, a movement, and an orientation of a welding tool based on an infrared emitter attached to said welding tool; and

a computer operatively interfacing to said infrared tracking system, said computer determining at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool,

wherein said computer determines for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter.

187. A method for tracking welding activity, said method comprising:

tracking by infrared at least one of a position, a movement, and an orientation of a welding tool based on an infrared emission from said welding tool;

determining at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool,

computing for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter.

188. A system for tracking welding activity, said system comprising:

an optical tracking system that tracks in real time or near real time at least one of a position, a movement, and an orientation of a welding tool; and

a computer operatively interfacing to said optical tracking system, said computer determining in real time or near *real time at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool,*

wherein said processor based computing device determines for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter, and

wherein said score relates to a weld quality of a real world weld.

189. The system of claim 188, wherein said determination of said score is performed in real time or near real time.

190. A system for tracking welding activity, said system comprising:

an infrared tracking system that tracks in real time or near real time at least one of a position, a movement, and an orientation of a welding tool based on an infrared element attached to said welding tool; and

a computer operatively interfacing to said infrared tracking system, said computer determining in real time or near real time at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool,

wherein said computer determines for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter, and

wherein said score relates to a weld quality of a real world weld.

191. The system of claim 190, wherein said determination of said score is performed in real time or near real time.

192. A method for tracking welding activity, said method comprising:

optically tracking in real time or near real time at least one of a position, a movement, and an orientation of a welding tool;

determining in real time or near real time at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool; and

computing for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter, and

wherein said score relates to a weld quality of a real world weld.

193. The method of claim 192, wherein said determination of said score is performed in real time or near real time.

194. A method for tracking welding activity, said method comprising:

tracking by infrared in real time or near real time at least one of a position, a movement, and an orientation of a welding tool based on an infrared element attached to said welding tool;

determining in real time or near real time at least one parameter that is at least one of a travel speed, a pitch angle, a roll angle, and an electrode distance to a center weld joint of said welding tool; and

computing for each of said at least one parameter a score based on a comparison of said parameter to at least one predetermined limit for said parameter, and

wherein said score relates to a weld quality of a real world weld.

195. The method of claim 194, wherein said determination of said score is performed in real time or near real time.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : RE45,398 E
APPLICATION NO. : 14/177692
DATED : March 3, 2015
INVENTOR(S) : Matthew Wayne Wallace

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims,

In column 9, line 63, delete “dynamic” and insert --[dynamic]--, therefor.

In column 11, line 51, delete “a” and insert --said--, therefor.

In column 12, line 46, delete “includes” and insert --include--, therefor.

In column 12, line 60, after “configured” insert --to--.

In column 13, line 7, before “intertial” insert --an--.

In column 13, line 43, delete “system” and insert --method--, therefor.

In column 13, line 44, delete “includes” and insert --include--, therefor.

In column 13, line 50, after “process” insert --in--.

In column 14, line 45, after “value” insert --corresponding to--.

In column 14, line 56, delete “includes” and insert --include--, therefor.

In column 15, line 8, after “configured” insert --to--.

In column 15, line 49, delete “includes” and insert --include--, therefor.

In column 15, lines 58-59, delete “based computing device” and insert --subsystem--, therefor.

In column 16, line 45, delete “system” and insert --method--, therefor.

Signed and Sealed this
Twenty-first Day of July, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

In column 16, line 46, delete “includes” and insert --include--, therefor.

In column 17, line 42, delete “system” and insert --method--, therefor.

In column 17, line 54, delete “processor based computing device” and insert --computer--, therefor.

In column 18, lines 11-12, delete “processor based computing device” and insert --computer--, therefor.

In column 18, lines 58-59, delete “processor based computing device” and insert --computer--, therefor.

In column 19, lines 33-34, delete “processor based computing device is further configured to record” and insert --computing further includes recording--, therefor.

In column 20, lines 9-10, delete “processor based computing device is further configured to record” and insert --computing further includes recording--, therefor.

In column 21, line 4, delete “processor based computing device” and insert --computer--, therefor.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : RE45,398 E
APPLICATION NO. : 14/177692
DATED : March 3, 2015
INVENTOR(S) : Matthew Wayne Wallace

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In Column 17, Line 2, delete “system” and insert --method--, therefor.

Signed and Sealed this
Tenth Day of January, 2017

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

(12) **INTER PARTES REVIEW CERTIFICATE** (1665th)
United States Patent (10) **Number: US RE45,398 K1**
Wallace (45) **Certificate Issued: Feb. 24, 2020**

(54) **SYSTEM FOR TRACKING AND ANALYZING WELDING ACTIVITY**

(71) Applicant: **Lincoln Global, Inc.**

(72) Inventor: **Matthew Wayne Wallace**

(73) Assignee: **Lincoln Global, Inc.**

Trial Number:

IPR2016-00840 filed Apr. 18, 2016

Inter Partes Review Certificate for:

Patent No.: **RE45,398**
Issued: **Mar. 3, 2015**
Appl. No.: **14/177,692**
Filed: **Feb. 11, 2014**

The results of IPR2016-00840 are reflected in this inter partes review certificate under 35 U.S.C. 318(b).

INTER PARTES REVIEW CERTIFICATE
U.S. Patent RE45,398 K1
Trial No. IPR2016-00840
Certificate Issued Feb. 24, 2020

AS A RESULT OF THE INTER PARTES REVIEW PROCEEDING, IT HAS BEEN DETERMINED THAT:

Claims **9-31**, **33-41**, **45-50**, **52-62**, **66-69**, **80-85**, **88-92**, **95-104**, **112-120**, **123-127**, **130-141**, **143-150**, **152-162**, **164-177** and **179-195** are cancelled.

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