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(54) **WIRELESS INTELLIGENT ULTRASOUND FETAL IMAGING SYSTEM**

(71) Applicant: **ANINGBO YOUCHANG ULTRASONIC TECHNOLOGY CO.,LTD**, Ningbo (CN)

(72) Inventor: **You Chong Tu**, Ningbo (CN)

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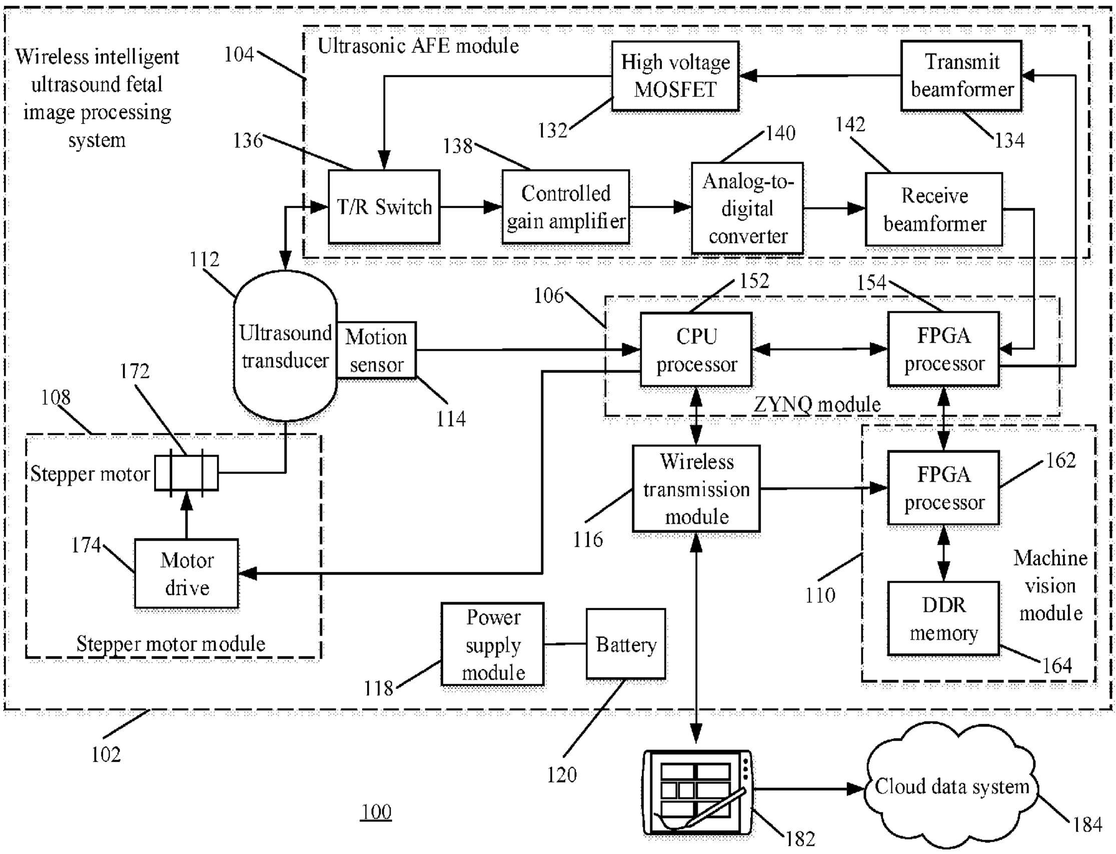
(57) **ABSTRACT**

A wireless intelligent ultrasound fetal imaging system includes an ultrasound transducer, an ultrasound AFE module, a ZYNQ module, a machine vision module and a mobile terminal. The ultrasound transducer transmits ultrasound wave toward a pregnant mother's fetal, and receives echo wave from the fetal. Through the ultrasound transducer, the ultrasound AFE module actuates transmission and reception of the ultrasound signal, and digitizes the received signals. The ZYNQ module performs image processing on the digital signals, and sends the processed image to the machine vision module for image recognition. The machine vision module conducts tracking and recognition of 3D and 4D images. The ZYNQ module also integrates the recognized image with the corresponding deflection angle of ultrasound transducer. The integrated image data is then sent to and displayed on the mobile terminal. The mobile terminal further accesses cloud computing resource for sharing and analyzing fetal images.



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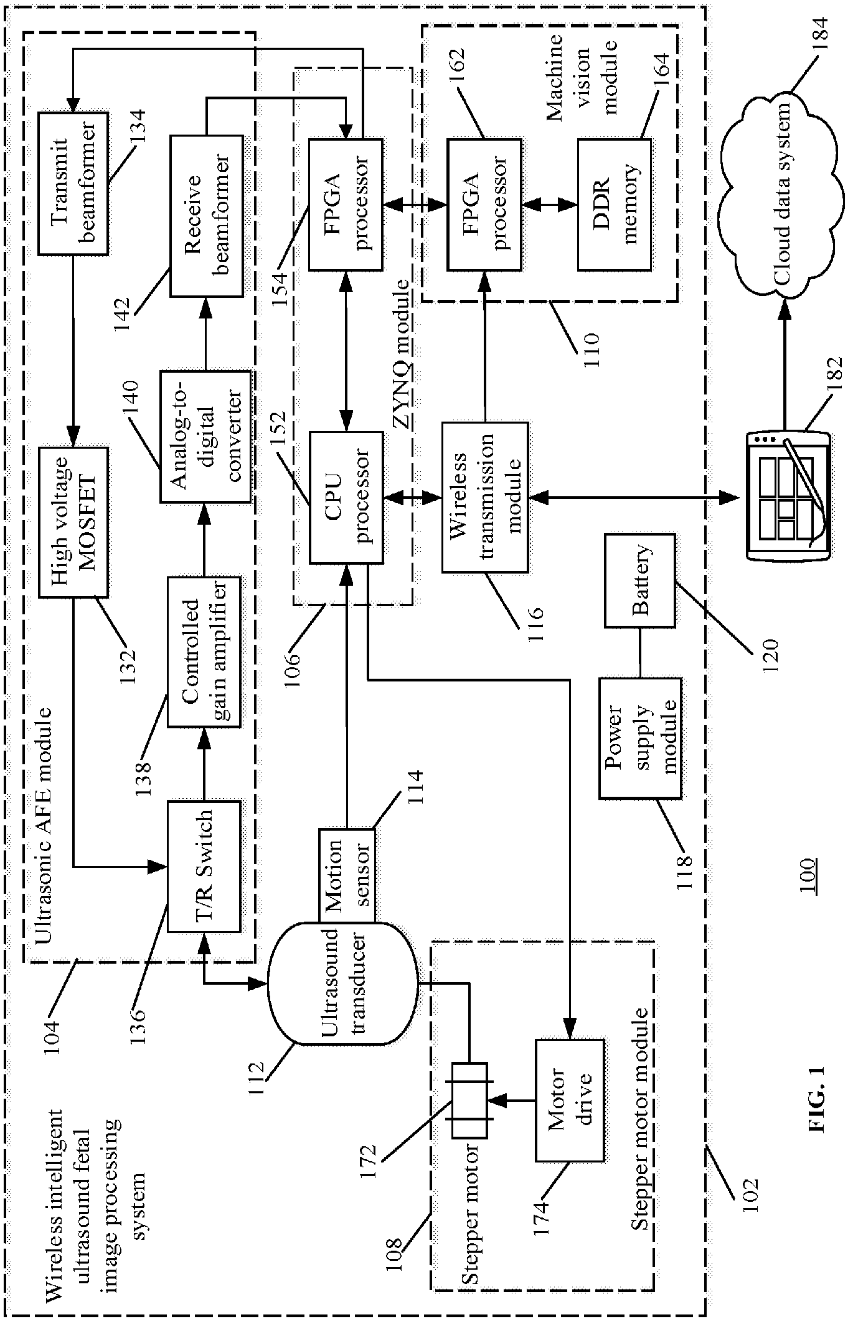
Wireless intelligent ultrasound fetal image processing system
102
Ultrasonic AFE module
104
Transmit beamformer
134
High voltage MOSFET
132
T/R Switch
136
Controlled gain amplifier
138
Analog-to-digital converter
140
Receive beamformer
142
ZYNQ module
106
FPGA processor
154
CPU processor
152
Machine vision module
110
FPGA processor
162
DDR memory
164
Wireless transmission module
116
Battery
120
Power supply module
118
Ultrasound transducer
112
Motion sensor
114
Stepper motor module
108
Stepper motor
172
Motor drive
174
182
Cloud data system
184
100

FIG. 1

WIRELESS INTELLIGENT ULTRASOUND FETAL IMAGING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit and priority of China Patent Application Number 201510554137.6, entitled "WIRELESS INTELLIGENT ULTRASOUND FETAL IMAGING SYSTEM," filed Sep. 2, 2015 and which is hereby incorporated by reference in its entirety. This application also claims the benefit and priority of PCT Patent Application Number PCT/CN2015/091443, entitled "WIRELESS INTELLIGENT ULTRASOUND FETAL IMAGING SYSTEM," filed Oct. 8, 2015 and which is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] The present invention generally relates to an ultrasound imaging system, and more particularly relates to a wireless intelligent ultrasound fetal imaging system. More particularly still, the present disclosure relates to a wireless intelligent ultrasound fetal image processing system operatively coupled to a mobile device.

DESCRIPTION OF BACKGROUND

[0003] A conventional ultrasound imaging system usually includes a probe, a host computer and a display unit. These components are linked by cables for data information transmission. Conventional ultrasound imaging systems have low portability. In other words, bulky conventional ultrasound imaging systems are inconvenient to carry and move around.

[0004] In addition, conventional ultrasound imaging systems impose high requirements on their operators. For example, operators of conventional ultrasound imaging systems must go through a professional training process. In particular, three dimensional ("3D") imaging and four dimensional ("4D") imaging features demand even higher requirements on the operators. Moreover, 3D fetal images and 4D fetal images can only be obtained by using extremely expensive conventional ultrasound imaging systems.

[0005] With rapid advancements in chip technologies in accordance with Moore's law, chip density becomes higher and higher while chips' physical dimension becomes smaller and smaller. In addition, chips are becoming more powerful at lower power consumption. Accordingly, integrated circuit technologies make small sized ultrasound imaging system equipment possible. Furthermore, rapid developments in machine vision technologies provide certain technological foundation for an intelligent 3D imaging system.

[0006] Communication technologies have advanced rapidly in last few decades as well. High speed broadband wireless communication technologies have obtained wide adoption worldwide, and make wireless imaging system possible.

[0007] Accordingly, there is a need for a wireless intelligent ultrasound fetal imaging system. There is a further need for a handheld wireless intelligent ultrasound fetal imaging system that generates 3D and 4D images.

SUMMARY OF THE DISCLOSURE

[0008] Generally speaking, pursuant to the various embodiments, the present disclosure provides a wireless intelligent ultrasound fetal imaging system. The wireless intelligent ultrasound fetal imaging system includes an ultrasound transducer. The ultrasound transducer is adapted to transmit ultrasound wave to a fetal and receive echo wave from the fetal. The system also includes an ultrasonic AFE module operatively coupled to ultrasound transducer. The ultrasonic AFE module is adapted to actuate transmission of the ultrasound wave, reception of the echo wave, and digitize the echo wave, thereby forming digitized signal. The system further includes a ZYNQ module operatively coupled to the ultrasound transducer and the ultrasonic AFE module. The ZYNQ module is adapted to perform image processing on the digitized signal, thereby forming a processed image. Furthermore, the system includes a machine vision module operatively coupled to the ZYNQ module. The machine vision module is adapted to receive the processed image from the ZYNQ module, recognize the processed image to form a recognized image, and send the recognized image to the ZYNQ module. The ZYNQ module integrates the recognized image with a deflection angle of the ultrasound transducer to form an integrated image. Moreover, the system includes a mobile terminal, and a wireless transmission module operatively coupled to the ZYNQ module and the machine vision module. The wireless transmission module is adapted to communicate with the mobile terminal over a wireless communication connection. The mobile terminal receives the integrated image from the wireless transmission module, and displays the integrated image on a screen of the mobile terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Although the characteristic features of this disclosure will be particularly pointed out in the claims, the invention itself, and the manner in which it may be made and used, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part hereof, wherein like reference numerals refer to like parts throughout the several views and in which:

[0010] FIG. **1** is a block diagram of a wireless intelligent ultrasonic imaging system in accordance with the teachings of this disclosure.

[0011] A person of ordinary skills in the art will appreciate that elements of the figures above are illustrated for simplicity and clarity, and are not necessarily drawn to scale. The dimensions of some elements in the figures may have been exaggerated relative to other elements to help understanding of the present teachings. Furthermore, a particular order in which certain elements, parts, components, modules, steps, actions, events and/or processes are described or illustrated may not be actually required. A person of ordinary skills in the art will appreciate that, for the purpose of simplicity and clarity of illustration, some commonly known and well-understood elements that are useful and/or necessary in a commercially feasible embodiment may not be depicted in order to provide a clear view of various embodiments in accordance with the present teachings.

DETAILED DESCRIPTION

[0012] Turning to the Figures and to FIG. **1** in particular, a simplified block diagram illustrating a wireless intelligent ultrasound fetal imaging system is shown and generally indicated at **100**. The wireless intelligent ultrasound fetal imaging system **100** includes a wireless intelligent ultrasound fetal image processing system **102** and a mobile communication device **182** operatively coupled to the processing system **102**. The mobile communication device **182** is also referred to herein a mobile terminal, a mobile device and a portable terminal. The mobile terminal **182** can be, for example, a tablet computer (also referred to herein as a PAD), a smartphone, a portable digital assistant device, a portable computer or a personal computer running one or more specialized computer programs (also referred to herein as computer software and computer software applications) written in computer programming languages, such as C, C++, C#, JAVA, OBJECT-C, etc.

[0013] The wireless intelligent ultrasound fetal image processing system **102** includes an ultrasound analog front-end ("AFE") module **104**, a ZYNQ module **106**, a stepper motor module **108**, a machine vision module **110**, an ultrasound transducer **112** operatively coupled to a motion sensor **114**, a power supply module **118** including, for example, a battery **120**, and a wireless transmission module **116** for communicating with the mobile terminal **182**. The ultrasound transducer **112** emits ultrasonic wave targeting a fetal residing within the body of the carrying mother, and receives echo wave. The ultrasonic AFE module **104** includes a high voltage metal-oxide-semiconductor field-effect transistor ("MOSFET") **132**, a transmit beamformer **134**, a transmit/receive ("T/R") switch **136**, a controlled gain amplifier **138**, an analog-to-digital converter ("ADC") **140** and a receive beamformer **142**. The ultrasonic AFE module **104** performs digital transmission of ultrasound wave, and reception and processing of echo signal. The ultrasonic AFE module **104** further digitizes the received echo signals.

[0014] The ZYNQ module **106** is an electronic module that includes a central processing unit ("CPU") processor **152** and a field-programmable gate array ("FPGA") processor **154**. The ZYNQ module **106** performs image processing on the digitized echo signals from the ultrasonic AFE module **104**, and generates a processed image. The ZYNQ module **106** then sends the processed image to the machine vision module **110** for recognition. In addition, the ZYNQ module **106** integrates the result of the recognition with the deflection angle data provided by the ultrasound transducer **112**, and sends the integrated data to the mobile terminal **182** via the wireless transmission module **116**.

[0015] The machine vision module **110**, including a FPGA processor **162** and a double date rate ("DDR") memory, implements real-time image recognition using comparison of characteristics between images, determines the correct image information without image integration or other processing, and completes tracking and recognition of 3D and/or 4D images. Real-time image recognition using comparison of characteristics between images includes establishing a database of image characteristics, conducting real-time comparison of such databases of images, and finding matching real-time image, which is the effective image.

[0016] The mobile terminal **182** controls the ZYNQ module **106**, process the data integrated by the ZYNQ module **106**, and displays the integrated data on a screen of the mobile terminal **182**. In one implementation, the mobile terminal **182** communicated with, for example, a cloud data system **184** (such as a cloud database or cloud data center) for data analysis and sharing. A user operates the mobile terminal **182** by interacting with the software application running on the mobile terminal device **182**.

[0017] The ultrasound transducer **112** achieves displacement through an actuating device. The ultrasound transducer **112** is connected to the motion sensor **114**, which obtains deflection angle data of the ultrasound transducer **112**. The deflection angle data is additional data for each image frame, and is sent to the ZYNQ module **106** for processing. It should be noted that the ultrasound transducer **112** includes multiple transducer units or two-dimensional array.

[0018] The actuating device includes a driving gear and the stepper motor module **108** including a stepper motor **172** and a motor drive **174**. The driving gear is disposed between the stepper motor **172** and the ultrasound transducer **112**. Through the driving gear, the ultrasound transducer **112** moves with the operation of the stepper motor **172**. The motion sensor **114** detects the movement of the ultrasound transducer **112**. The ZYNQ module **106**, controlled by the mobile terminal **182**, controls the starting and stopping of the stepper motor module **108**, and other functions of the system **102**, such as signal processing.

[0019] Signals transmitted by the ultrasonic AFE module **104** is generated by the transmit beamformer **134**. The high voltage MOSFET **132** converts the generated signals into high voltage signals. The T/R switch **136** functions to excite the ultrasound transducer **112**. After the ultrasonic signals are transmitted, the transducer **112** enters into a reception cycle. Through the T/R switch **136**, echo signals from the fetal enter the controlled gain amplifier **138**. The amplified echo signals are then processed by the ADC **140**. The receive beamformer **142** then receives the converted signals from the ADC **140**, and converts them into digital beam signals.

[0020] Within the ZYNQ module **106**, the CPU processor **152** and the FPGA processor **154** are operatively coupled with each other and can communicate with each other. For example, the processors **152-154** exchange data. The FPGA processor **154** controls the transit beamformer **134** to transmit signals, and process digital beam signals output from the receive beamformer **142**. The FPGA processor **154** is also operatively coupled to the machine vision module **110**. The CPU processor **152** is operatively coupled to the motion sensor **114**, the stepper motor module **108** and the wireless transmission module **116**.

[0021] The FPGA processor **162** and the FPGA processor **154** are operatively coupled to each other and communicate data to each other. The data processed by the FPGA processor **162** is stored in the DDR **164**. The mobile terminal **182** communicates with the wireless transmission module **116** using, for example, WiFi, wireless USB, long term evolution ("LTE") fourth generation ("4G"), LTE fifth generation ("5G"), or other wireless communication technologies.

[0022] The power supply module **118** provides electric power to other components of the wireless intelligent ultrasound fetal image processing system **102**, such as the stepper motor module **108**, the ultrasonic AFE module **104**, the ZYNQ module **106**, the machine vision module **110**, the ultrasound transducer **112**, etc. The power supply module **118** can include, for example, a high voltage power supply, a lower voltage power supply generating circuit, a battery charge and discharge controller, or a rechargeable battery.

[0023] The software application running on the mobile terminal **182** processes data and controls various components of the wireless intelligent ultrasound fetal image processing system **102**. Accordingly, compared to conventional fetal imaging systems, the system **100** generates 3D and 4D fetal images faster, imposes lower requirements on the operator's training on the system **100**, is a handheld system, and intelligently generates 3D and 4D fetal images by automatically tracking fetal images using the machine vision module **110**. Due to its portability, the system **100** can be deployed at hospitals and any other facilities to ease the operation and use of the system **100** by its intended users. In addition, in the system **100**, fetal image data and parameters for controlling the system **102** are transmitted wirelessly. Furthermore, the system **100** can be operatively coupled to the Internet for accessing cloud computing power, such as the cloud data center **184**. For the example, the terminal **182** can store image data in the cloud data center **184**, from where other users (such as a doctor) can access the fetal images generated by the system **100**. The generation, transmission, analysis and feedback of fetal images are automatic features of the system **100**. In other words, the system **100** can be used and operated by laymen without medical training, and thus dramatically improves productivity.

[0024] To operate the wireless intelligent ultrasound fetal imaging system, a user operates the mobile terminal **182** and launches and interacts with the software application running on the mobile terminal **182**. The user enters one or more values for control parameters. The software application then controls the mobile terminal **182** to configure the wireless intelligent ultrasound fetal image processing system **102** by setting various control parameters of the system **102**. Via the wireless transmission module **116**, the CPU **152** receives the parameters' values, and processes the parameters. The CPU **152** also sends relevant processed parameters to the FPGA processor **154**. Under the control of such parameters, the FPGA processor **154** controls the transmission of ultrasound wave from the ultrasonic AFE module **104**, and reception of echo signal. The ultrasound wave is targeted to the carrying mother of a fetal.

[0025] The transmit beamformer **134** generates emission signals, which are converted into high voltage signals by the MOSFET **132**. The T/R switch **136** then excites the ultrasound transducer **112** to send the ultrasound wave to the carry mother's body. After the transmission, the ultrasound transducer **112** enters into a reception cycle. Through the T/R switch **136**, echo signal from the fetal and the fetal's surrounding area enter the amplifier **138**. The amplified signals are converted into digital signals by the ADC **140**. The digital signals enter the receive beamformer **142**. In response, the beamformer **142** generates beam signals.

[0026] To achieve accurate control over 3D data, the ultrasound transducer **112** is operatively coupled to the stepper motor **172**. The CPU processor **152** controls the rotation angle of the stepper motor **172** based on parameters received from the mobile terminal **182**. For every stepping unit the stepper motor **172** deflects or moves, one image of the fetal is generated. At the same time, the motion sensor **114** accurately obtains the deflection angle of the ultrasound transducer **112**. The deflection angle is a piece of metadata of the image frame, and associated with the image frame.

[0027] Digital beam signal is sent to the FPGA processor **154** for image processing. The output data is then transmitted to the FPGA processor **162** for data recognition processing. The output from the FPGA processor **162** is then sent back to the FPGA processor **154** for data integration. The CPU processor **152** then, through the wireless transmission module **116**, sends the integrated data to the terminal **182**, and displays the data on the terminal's **182** screen. The mobile terminal **182** optionally sends the data (meaning fetal images) to the cloud data center **184** for further analysis and sharing.

[0028] Obviously, many additional modifications and variations of the present disclosure are possible in light of the above teachings. Thus, it is to be understood that, within the scope of the appended claims, the disclosure may be practiced otherwise than is specifically described above without departing from the true spirit and scope of the present invention.

[0029] The foregoing description of the disclosure has been presented for purposes of illustration and description, and is not intended to be exhaustive or to limit the disclosure to the precise form disclosed. The description was selected to best explain the principles of the present teachings and practical application of these principles to enable others skilled in the art to best utilize the disclosure in various embodiments and various modifications as are suited to the particular use contemplated. It should be recognized that the words "a" or "an" are intended to include both the singular and the plural. Conversely, any reference to plural elements shall, where appropriate, include the singular.

[0030] It is intended that the scope of the disclosure not be limited by the specification, but be defined by the claims set forth below. In addition, although narrow claims may be presented below, it should be recognized that the scope of this invention is much broader than presented by the claim (s). It is intended that broader claims will be submitted in one or more applications that claim the benefit of priority from this application. Insofar as the description above and the accompanying drawings disclose additional subject matter that is not within the scope of the claim or claims below, the additional inventions are not dedicated to the public and the right to file one or more applications to claim such additional inventions is reserved.

What is claimed is:

1. A wireless intelligent ultrasound fetal imaging system comprising:

i) an ultrasound transducer, said ultrasound transducer adapted to transmit ultrasound wave to a fetal and receive echo wave from said fetal;

ii) an ultrasonic AFE module operatively coupled to ultrasound transducer, said ultrasonic AFE module adapted to actuate transmission of said ultrasound wave, reception of said echo wave, and digitize said echo wave, thereby forming digitized signal;

iii) a ZYNQ module operatively coupled to said ultrasound transducer and said ultrasonic AFE module, said ZYNQ module adapted to perform image processing on said digitized signal, thereby forming a processed image;

iv) a machine vision module operatively coupled to said ZYNQ module, said machine vision module adapted to receive said processed image from said ZYNQ module, recognize said processed image to form a recognized image, and send said recognized image to said ZYNQ module, wherein said ZYNQ module integrates said recognized image with a deflection angle of said ultrasound transducer to form an integrated image;

v) a mobile terminal;

vi) a wireless transmission module operatively coupled to said ZYNQ module and said machine vision module, said wireless transmission module adapted to communicate with said mobile terminal over a wireless communication connection; and

vii) wherein said mobile terminal receives said integrated image from said wireless transmission module, and displays said integrated image on a screen of said mobile terminal.

2. The wireless intelligent ultrasound fetal imaging system of claim **1** further comprising a motion sensor and a stepper motor module, said motion sensor operatively coupled to said ultrasound transducer, said stepper motor module having a stepper motor, said ultrasound transducer moving with the operation of said stepper motor through an actuating device, said motion sensor obtaining a deflection angle of said ultrasound transducer and sending said deflection angle to said ZYNQ module.

3. The wireless intelligent ultrasound fetal imaging system of claim **2**, wherein said ultrasound transducer includes multiple transducer units or a two-dimensional array.

4. The wireless intelligent ultrasound fetal imaging system of claim **2**, wherein said actuating device includes a driving gear and said stepper motor module, said ZYNQ module controlling a starting and a stopping of said stepper motor module.

5. The wireless intelligent ultrasound fetal imaging system of claim **2**, wherein said ultrasonic AFE module include a T/R switch, a high voltage MOSFET, a transmit beamformer, a controlled gain amplifier, an analog-to-digital converter and a receive beamformer, wherein:

i.) said ultrasound wave is generated by said transmit beamformer and amplified by said controlled gain amplifier;

ii.) said T/R switch excites said ultrasound transducer for transmitting said ultrasound wave;

iii.) said ultrasound transducer enters a reception cycle after transmission of said ultrasound wave;

iv.) said controlled gain amplifier amplifies said echo wave, thereby forming amplified signal;

v.) said analog-to-digital converter converts said amplified signal into digital signal; and

vi.) said receive beamformer converts said digital signal into beam signal.

6. The wireless intelligent ultrasound fetal imaging system of claim **5**, wherein said ZYNQ module includes a CPU processor and a first FPGA processor, said CPU processor and said first FPGA processor adapted to exchange data, said first FPGA processor controlling said transmit beamformer and said receive beamformer, said CPU processor operatively coupled to said motion sensor, said stepper motor module and said wireless transmission module, said first FPGA processor operatively coupled to said machine vision module.

7. The wireless intelligent ultrasound fetal imaging system of claim **6**, wherein said machine vision module includes a second FPGA processor and a DDR memory, said first FPGA processor communicating with said second FPGA processor for data exchange, said DDR memory storing data output from said second FPGA processor.

8. The wireless intelligent ultrasound fetal imaging system of claim **2**, wherein said wireless transmission module communicates with said mobile terminal over a WiFi connection, a wireless USB connection, a 4G connection or a 5G connection.

9. The wireless intelligent ultrasound fetal imaging system of claim **2** further comprising a power supply module providing power for said ultrasound transducer, said stepper motor module, said ZYNQ module, said machine vision module and said ultrasonic AFE module, said power supply module including a high voltage power supply, a lower voltage power supply generating circuit, a battery charge and discharge controller or a rechargeable battery.

10. The wireless intelligent ultrasound fetal imaging system of claim **2**, wherein said mobile terminal is a smart phone, a PAD or a personal computer, and wherein said mobile terminal runs a software application.

11. The wireless intelligent ultrasound fetal imaging system of claim **2**, wherein said mobile terminal sends said integrated image to a cloud data center for data.

* * * * *

专利名称(译)	无线智能超声胎儿成像系统		
公开(公告)号	US20170055955A1	公开(公告)日	2017-03-02
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[标]申请(专利权)人(译)	aningbo佑昌超声波科技有限公司		
申请(专利权)人(译)	aningbo佑昌超声波科技有限公司，LTD		
当前申请(专利权)人(译)	aningbo佑昌超声波科技有限公司，LTD		
[标]发明人	TU YOU CHONG		
发明人	TU, YOU CHONG		
IPC分类号	A61B8/08 A61B8/00 A61B8/14		
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外部链接	Espacenet USPTO		

摘要(译)

无线智能超声胎儿成像系统包括超声换能器，超声AFE模块，ZYNQ模块，机器视觉模块和移动终端。超声换能器朝向怀孕母亲的胎儿发射超声波，并从胎儿接收回波。通过超声波换能器，超声AFE模块致动超声信号的发送和接收，并且数字化接收的信号。ZYNQ模块对数字信号进行图像处理，并将处理后的图像发送到机器视觉模块进行图像识别。机器视觉模块进行3D和4D图像的跟踪和识别。ZYNQ模块还将识别的图像与超声换能器的相应偏转角集成。然后将集成的图像数据发送到移动终端并在移动终端上显示。移动终端还访问云计算资源以共享和分析胎儿图像。