Electrical, Computer & Energy Engineering
UNIVERSITY OF COLORADO BOULDER

AVoCauterizers

Medtronic

AI-Assisted Voice-Controlled Electrosurgical Generator (AVoC)

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Background

Figure 1. Left: FT10 electrosurgical generator [1]. Right: an ESG cutting tool [2].

Electrosurgical generators (ESGs) such as Medtronic's FT10 are used to power electric surgical tools which can cut tissue, cauterize blood vessels, etc. The FT10 offers variable power levels with every surgical mode.

Unfortunately, ESGs are not sterile equipment, so surgeons need to ask someone else outside the sterile field to change the mode and power level while they operate.

Additionally, Medtronic has a team dedicated to developing machine learning algorithms to improve the functionality of the FT10 but they lack extensive data that is sufficiently unbiased and contextually annotated.

Objectives

→ **Add voice control to the FT10**

This alleviates the need for an additional OR staff member to be available to control the FT10.

[3]

→ **Collect and synchronize contextual data**

The FT10 collects unlabeled electrical data. The AVoC collects data from 2 HD video inputs, a microphone, and up to 6 variable analog sensor inputs all of which are synchronized to the FT10's electrical data and displayed in an interactive GUI. The synchronization latency between the analog sensor data and the FT10 electrical data is less than 10ms.

System Diagram

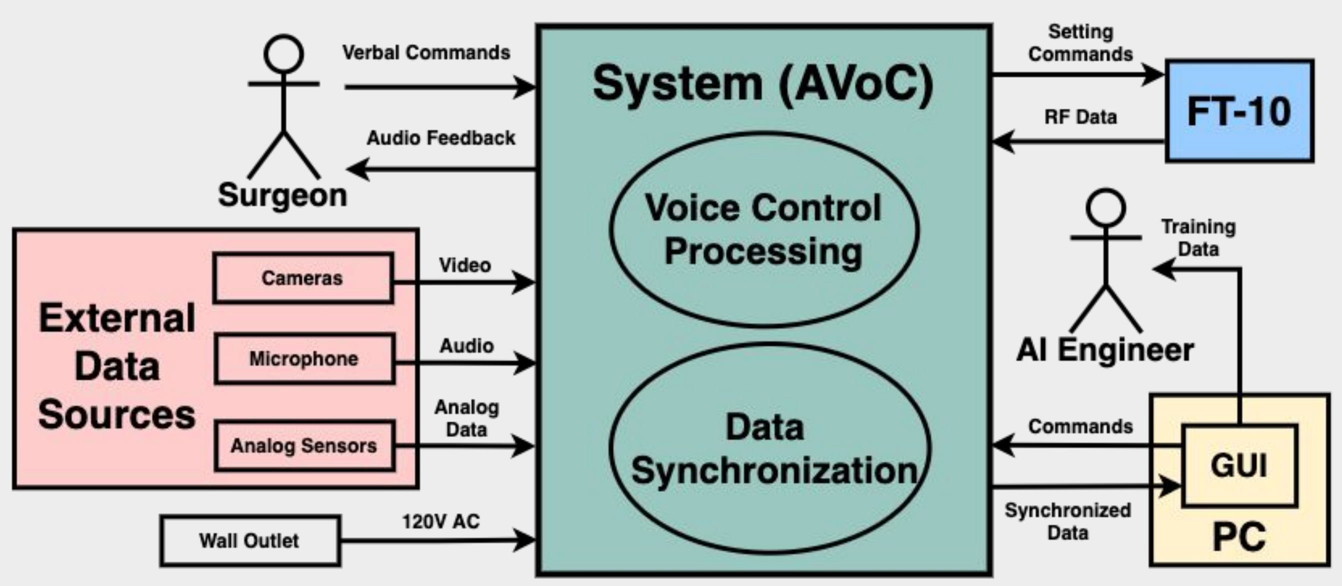

Figure 2. AVoC System Diagram

During an operation, the AVoC collects audio, video, and analog sensor data from external devices which is timestamped and stored in raw format on an SD card by the data synchronization software on the PCB's processor. Once the procedure is done, the data is synchronized with the FT10 electrical data and transferred to an external PC where it can be viewed and analyzed by Medtronic's engineers in an interactive graphical user interface (GUI).

During a procedure, the voice control processing software is running in parallel on the PCB to recognize audio commands. If a valid command is detected, the node relays the command to the FT10 via Medtronic's secure proprietary middleware to change the FT10 settings. All the while, the AVoC provides audible feedback to the user.

Software

Data Synchronization

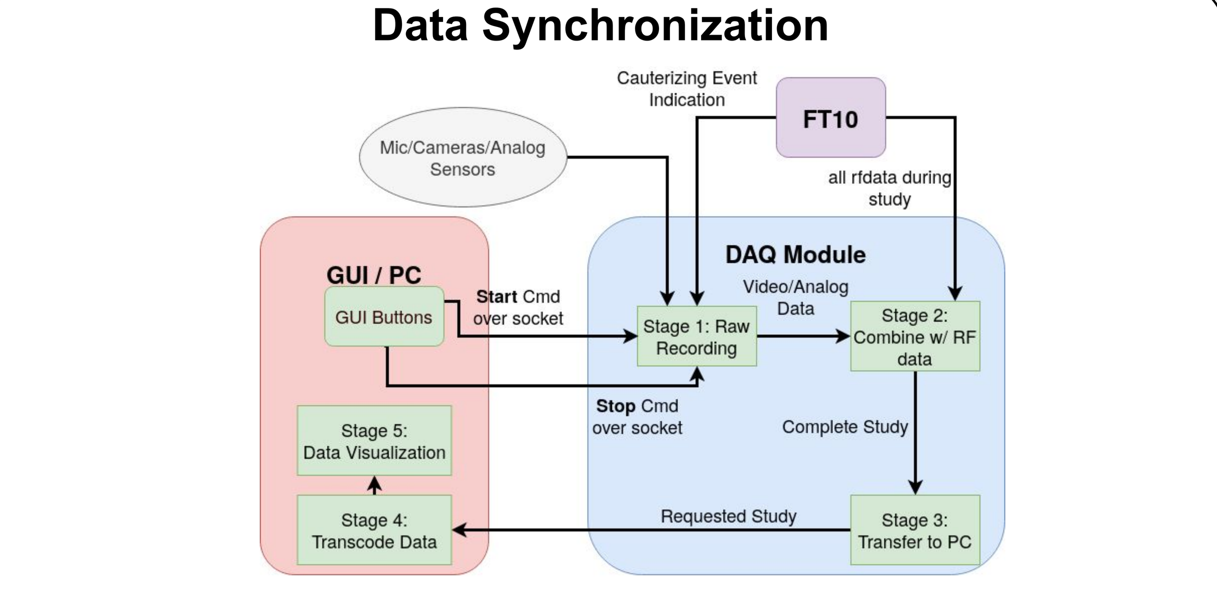

Figure 3. Data collection/synchronization software flow diagram

Data synchronization is initiated by the GUI. The PCB records analog, video and the FT10's RF data. This data is aggregated into a "Study." The GUI transfers the study from the PCB to the PC. Synchronized visualization begins once the Study has been received and loaded on the PC.

Voice Control

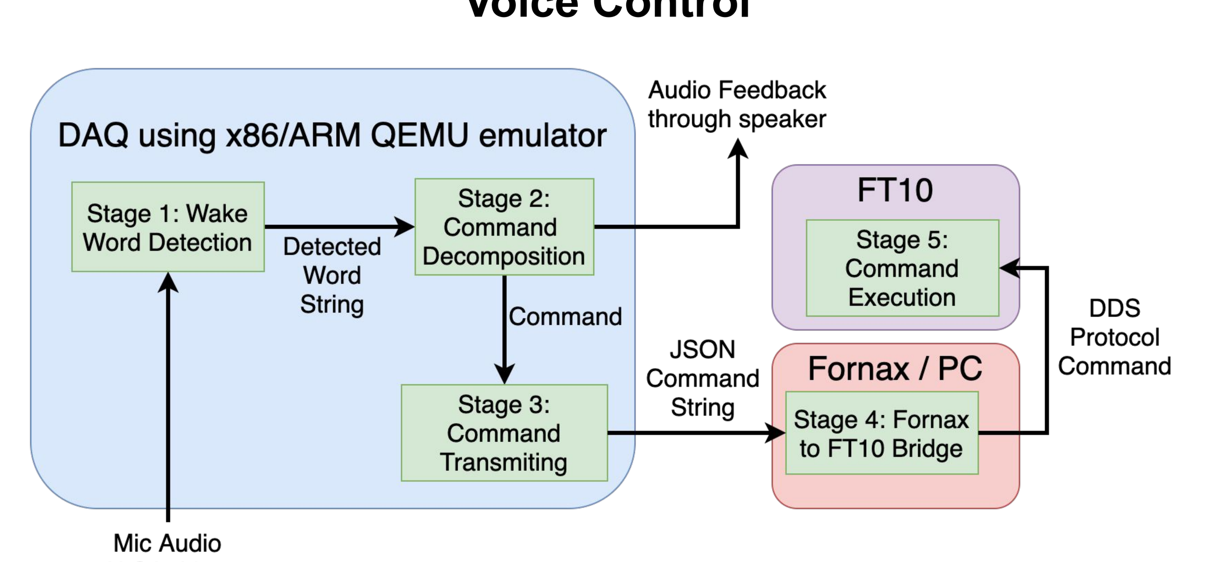

Figure 4. Voice control software flow diagram

Voice Control primarily runs on the AVoC PCB inside the QEMU x86 virtual environment. Porcupine, the high accuracy and locally running voice recognition software we used, only provides x86 binaries. Recognized commands are sent over TCP to Fornax running on a PC before being transferred to the FT10.

Hardware

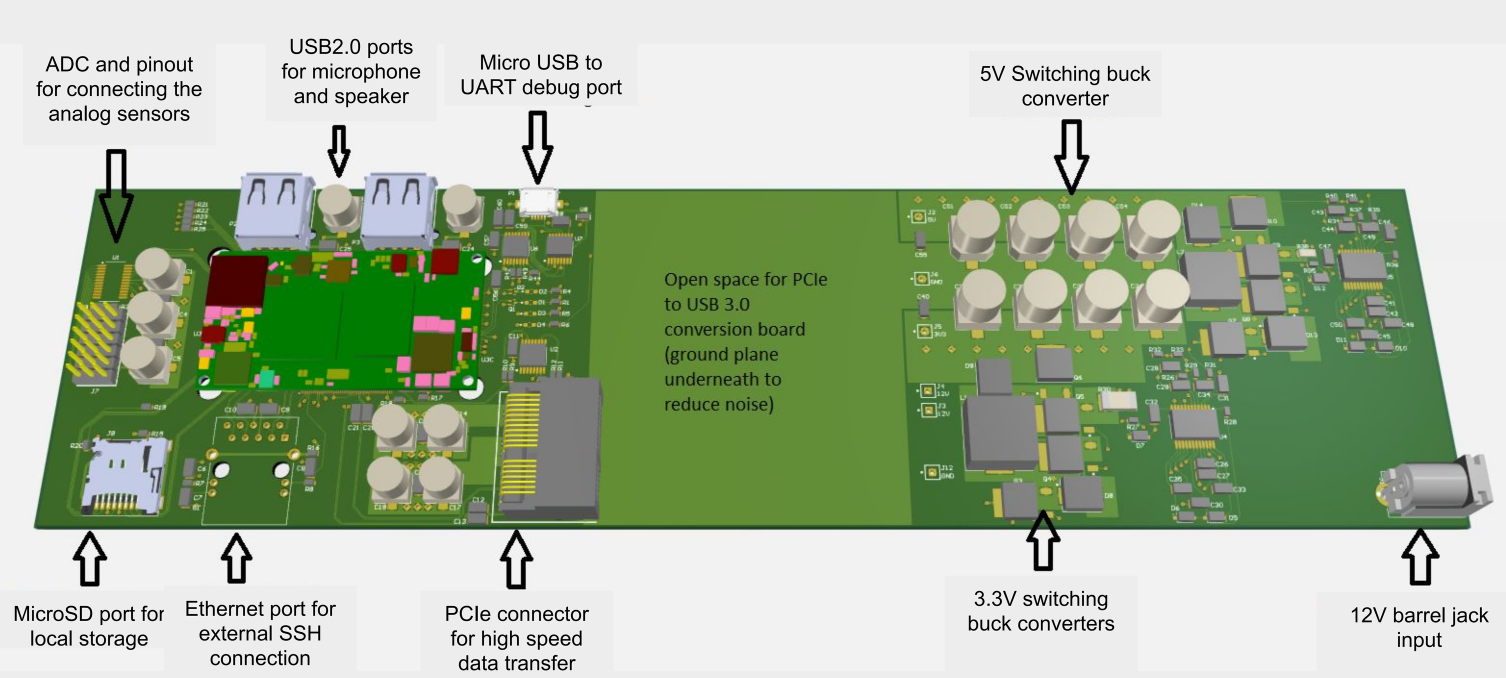

Figure 5. 3D rendering of main PCB

To accommodate the bandwidth demands of handling 2 (potentially uncompressed) HD video streams in addition to running the voice control processes, a 4-core 1.8GHz ARM Cortex-A53 was decided to be the best processor. In order to forego the hardware challenge of routing DRAM, the PCB has a DART-MX8M-MINI System On Module (SOM). The SOM is connected to the PCB using three 90-pin connectors. From these connectors, the SOM is routed to all the necessary data busses and voltage lines. The board takes in 12VDC from a barrel jack which is regulated by buck converters to 5V and 3.3V to power the SOM, the external USB connectors, and an external commercial PCIe-USB 3.0 adaptor board. The commercial adaptor board is necessary because the SOM can only support the desired video bandwidth over PCIe and the external cameras connect to USB. In Figure 6 to the right, the power electronics are separated from the main PCB to reduce the failure-points during preliminary testing. In the final design (Figure 5), the boards have been combined into one PCB.

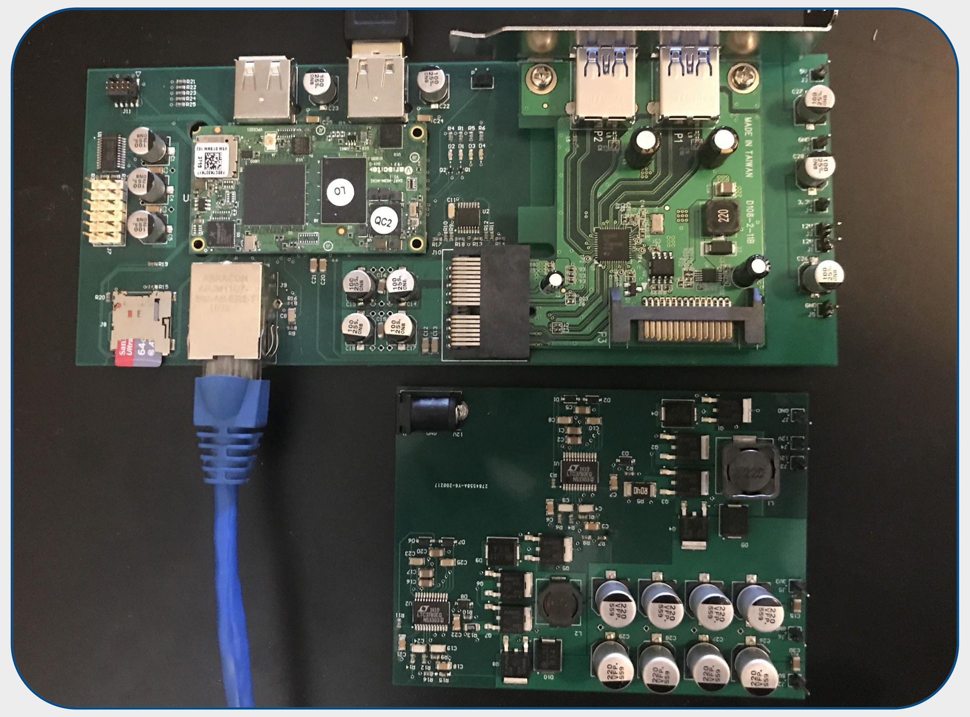

Figure 6. Custom hardware. Top: main PCB. Bottom: power PCB.

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GUI

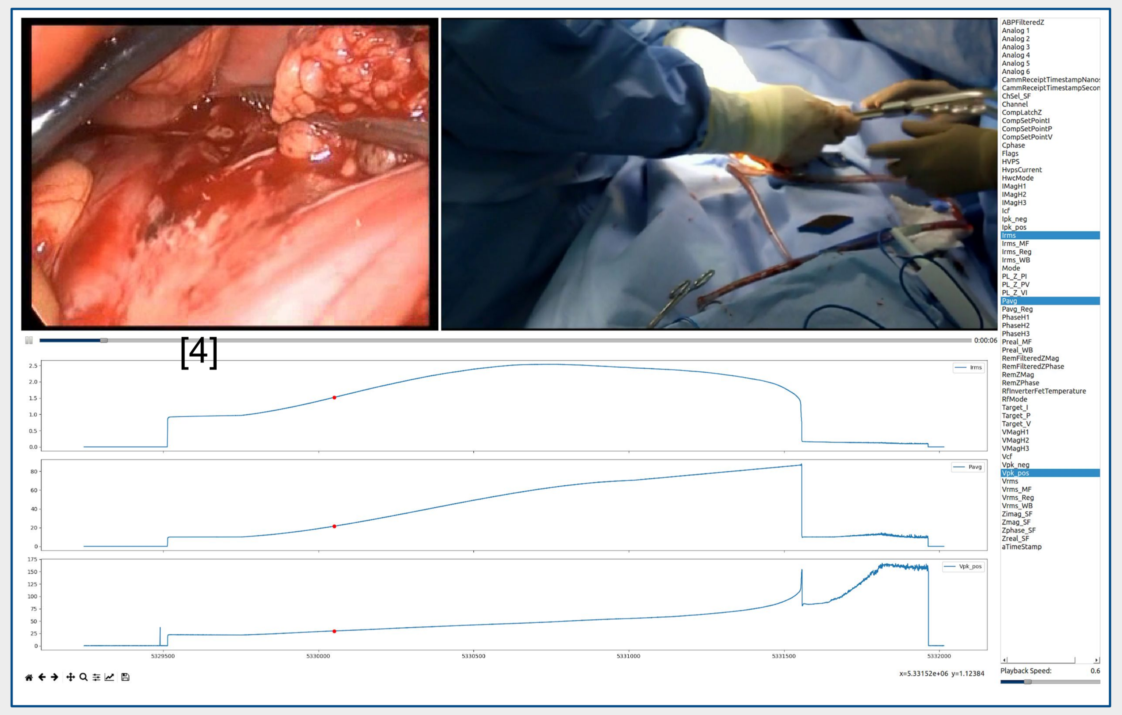

Figure 7. GUI data visualization screen

In the GUI, Medtronic engineers can view the footage from up to two connected cameras to find portions of the surgery which are of interest. From there the engineer can view all of the data from the FT10 and the analog sensors at the bottom of the screen on a plot with adjustable timescale. The video frames are synchronized with the highlighted point on the data display so that acquired data from the FT10 and the analog sensors can be understood in the context of the visual data from the videos.

Conclusion / Future Work

The AVoC is able to recognize over 20 phrases, resulting in greater than a hundred possible setting changes. Future work may include scaling the number of setting changes and giving the VC node DDS support, so the Fornax relay is not needed. The data acquisition node has demonstrated its ability to synchronize three streams of data and display them in an effective manner. Video data streams were limited to 10Hz due to USB2 bandwidth limitations. Mistakes were made in the initial PCIe PCB design, so future work will not have such limitations by utilizing the high bandwidth PCIe BUS initially intended to be available.

[1] FT10 Energy Generator (Esu). (n.d.). Retrieved from https://avantehs.com/p/valleylab-ft10-energy-platform-generator/13836
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[3] Murry, J. (n.d.). Speech Icon. Retrieved from https://pixabay.com/users/mcmurryjulie-2375405/
[4] Di Saverio S, Et al. (2014). "Diagnosis and treatment of perforated or bleeding peptic ulcers: 2013 WSES position paper". World Journal of Emergency Surgery. DOI:10.1186/1749-7922-9-45. PMID 25114715. PMC: 4127969