SensorBox™

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We work on the development of a **Visual AI research platform**, we call the **SensorBox™**.

R&D (Research and Development) of a Visual AI (Artificial Intelligence) system requires the use of a flexible embedded sensor suite that allows for experimentation and that can be used in the real environment. Using available benchmark datasets can only get you so far, and may not even be representative for your particular application. Building such a sensor suite can be quite complex and arguably is not really part of developing a software application.

Our goal is to build a research platform that can be used to develop state estimation, mapping and scene understanding applications. Our sensor suite consists of **stereo RGB cameras**, a **RGB-Depth camera**, a **thermal camera**, an **ultrasonic range finder**, a **GNSS** (Global Navigation Satellite System) receiver, **IMU**s (Inertial Measurement Unit), a **pressure sensor**, a **temperature sensor** and a **power sensor**. Our embedded processing platform consists of an **Arduino Zero** microcontroller and an **NVIDIA Jetson Xavier NX**. Our embedded power source consists of a **USB-C power bank**.

As a research platform, we are looking for maximum flexibility and re-use. We leverage existing and popular eco-systems for robotics, computer vision and artificial intelligence, in particular the **NVIDIA Jetson** embedded processing platform, **SparkFun**'s microcontroller and sensors and **Arducam**'s suite of cameras.

So far, we completed the design, 3D printing, hardware assembly and basic software setup. Next, we are going to work on a ROS2 based infrastructure, a qt-based GUI, sensor calibration and sensor synchronization.

We provide a **GitHub repository** with all design and source code files and detailed documentation with step-by-step instructions and **YouTube videos** on how to build the SensorBox™.

aiWerkstatt™ provides the **SensorBox™** as an **open source product** in the hope that it will provide researchers in Visual AI with a jump start and when used by many that it will enable collaborations and create synergies.

Sensors & Processing

Embedded Processor

NVIDIA provides with the Jetson product family a powerful embedded processing platform with a rich eco-system for robotics, computer vision and artificial intelligence.

We use a NVIDIA Jetson Xavier NX development kit for our processing with consideration of the NVIDIA Jetson Orin NX as a future drop-in replacement. The NDIVDIA Jetson Xavier NX is equipped with a 6-core ARM® v8.2 64-bit CPU 6MB L2 + 4MB L3, a 384-core NVIDIA Volta™ GPU with 48

Tensor Cores, 2 LVDLA engines, a 7-way VLIW Vision Processor, providing 21 TOPs. It has 2 power modes: 10W and 15W. It allows to connect up to 6 cameras directly via MIPI CSI-2. The development kit provides 2 MIPI CSI-2 connectors. The development kit is already equipped with a M.2 Key E wifi and bluetooth module and 2 antennas. We added a M.2 Key M 500GB SSD drive. The NDIVDIA Jetson Xavier NX development kit requires a SD card to boot.

Microcontroller

SparkFun provides a rich eco-system of microcontrollers and sensors for robotics, computer vision and artificial intelligence. SparkFun provides Arduino Libraries for easy programming of their products.

We use the SparkFun RedBoard Turbo development board, which at its heart is an Arduino Zero with an ATSAMD21G18 32-bit/48MHz ARM Cortex-M0+microcontroller. The RedBoard Turbo is equipped with a USB interface for programming and power, a UF2 bootloader, 4MB flash memory, a Qwiic I2C connector, and a RTC (Real-Time Clock).

Sensors

We use a suite of sensors from SparkFun that can be connected easily via Qwiic I2C connectors.

GNSS (Global Navigation Satellite System)
We use the SparkFun NEO-M9N GPS breakout board that comes with an integrated chip antenna. The Neo-M9N module is a 92-channel u-blox M9 GNSS receiver, which can receive signals from GPS, GLONASS, Galileo and BeiDou providing an accuracy of ~1.5m. The breakout board is equipped with an on-board rechargeable battery that provides power to the RTC (Real-Time Clock) and GNSS orbit data allowing to reduce the time-to-first fix from a cold start (~24s) to a hot start (~2s). U-blox provides a proprietary binary API.

IMU (Inertial Measurement Unit)
We use the SparkFun ICM20948 9DoF IMU. The ICM20948 IMU includes a 3-axis gyroscope with user-programmable ranges: ±250, 500, 1000, and 2000 dps (degrees per second), a 3-axis accelerometer with user-programmable ranges: ±2, 4, 8, and 16g, a 3-axis magnetometer with a wide range of ±4900 µT and a temperature sensor. It can be synchronized from an external source (FSNC pin). It includes a Digital Motion Processor for on-sensor processing that allows to trigger interrupts (INT pin).

Pressure (air) Sensor
We use the SparkFun LPS25HB Pressure Sensor. The LPS25HB pressure sensor provides absolute pressure measurements from 26 kPa to 126 kPA with a precision of 1Pa RMS (8 cm at sea level) and 24-bit resolution from 1 to 25Hz.

Temperature (internal) Sensor
We use the SparkFun TMP102 Temperature Sensor. The TMP102 temperature sensor provides temperature measurements from -55C to +128C with a precision of ±0.5°C and 12-bit resolution from 0.25 to 8Hz. Programmable temperature limits can be used to trigger an interrupt (ALERT pin).

Vision

Stereo RGB (rolling-shutter) Cameras

Arducam provides a whole suite of cameras that can be used with the NVIDIA Jetson Xavier NX. Note that the Sony IMX218 and IMX417 are supported natively by the NVIDIA Jetson Xavier NX.

Many applications today are trying to take advantage of the small camera modules developed for the cell phone market. Note that most of them are rolling shutter cameras, which come with some additional complexity when it comes to synchronization or registration. We use a Arducam 8MP IMX219 Camera Module (with PCB). The cameras are connected directly to the 2 NVIDIA Jetson Xavier NX MIPI CSI-2 ports.

Optional: IMU (Inertial Measurement Unit)

We use the SparkFun LSM9DS1 9DoF IMU with the SparkFun Qwiic Adapter to provide the RGB cameras with their own IMUs. This is optional, because the cameras are fixed and we already have the SparkFun ICM20948 IMU in the SensorBox. It is intended here for prototyping the electronics for small-footprint independent moving cameras. The LSM9DS1 IMU includes a 3-axis gyroscope with user-programmable ranges: ±245, 500, or 2000 dps (degrees per second), a 3-axis accelerometer with user-programmable ranges: ±2, 4, 8, or 16g, and a 3-axis magnetometer with user-programmable ranges: ±4, 8, 12, or 16gauss.

RGB-D Camera

We use the Intel Realsense D435i with integrated IMU. The Intel Realsense is connected via USB 3.1 to the NVIDIA Jetson Xavier NX. The depth image can be provided at 90Hz with a native resolution of 848x480 pixels and a FOV of 87H x 58V (95D) degrees. The IR cameras are standard mono-chrome camera without an IR cut filter with a FOV of 91H x 65V (100D) degrees. The IR projector provides a random dot pattern at a wavelength of 850 nanometers with a FOV of 86H x 57V (94D) degrees.

Thermal Camera

We use the FLIR Lepton 3.5 with the PureTermal 2 FLIR Lepton Smart I/O Module that provides a USB 2 interface that is connected to the NVIDIA Jetson Xavier NX. The FLIR Lepton 3.5 provides calibrated radiometric images from a wavelength band from 8 to 14 microns (vs human visible spectrum is from 380 to 740 nanometers) at 8.7Hz with a resolution of 160x120 pixels and a FOV of 56H (71D) degrees.

Ultrasonic Range Finder

We use the MaxBotix HRLV-MaxSonar-EZ4 Ultrasonic Range Finder that provides about 1mm resolution from 0.3 to 5m (with no dead zone: <0.3m range at 0.3m) at 10Hz working with 42kHz ultrasound waves and a small beam angle for air ranging. The Ultrasonic Range Finder provides internal temperature based speed of sound compensation.

Power

USB-C Power Bank

We use the POWER ADD USB-C power bank as power source. It auto-starts when a device is plugged in, no need to push a button. It auto-starts when a contact was made after a lost of contact, making sure it keeps charging. It provides about 27,000mAh (airline safe) and 100Wh. It has an USB-C input port that allows to use a 100W (20Vx5A) USB-C charger, and with pass-through charging that allows us to use the SensorBoard while charging. It has a separate USB-C output port that can provide up to 60W (20Vx3A), which is well suited to power the entire SensorBox. With our 65W USB-C charger it takes about 4 hours to fully charge the SensorBox. Note that the POWER ADD power bank shows that it is down to 1% charge when it actually reaches about 20%. Don’t be fooled.

USB-C Power Delivery
We use the SparkFun USB-C Power Deliver Board wired up to a power barrel jack connector (center pin positive) to deliver up to 30W (20V@1.5A) to the NVIDIA Jetson Xavier NX. The NVIDIA Jetson Xavier NX then in turn powers all other devices in the SensorBox. We use a power button connected between the USB-C PD and the power barrel jack to switch on/off the power to the NVIDIA Jetson Xavier NX. Be aware that a USB-C power bank that is permanently connected to a USB-C PD is going to loose its charge slowly over time. We seem to loose 8% of the charge per day, meaning that the SensorBox is completely discharged after 12 days. Make sure to recharge the SensorBox when not used for some time before going into the field.

Current and Voltage Sensor
We use the Zio INA219 Current and Voltage Sensor to monitor the power consumption of the SensorBox.

Cover

Display

We use the UCTRONICS 5 Inch Touch Screen as an integrated display in the cover and connect it via HDMI and USB (power and mouse) to the NVIDIA Jetson Xavier NX.

Monitor, Keyboard, Mouse and Power

The SensorBox can be used as a stand-alone computer powered through the USB-C connector with an external HDMI monitor using the HDMI connector, and a keyboard and mouse using NVIDIA Jetson Xavier NX bluetooth module.