AUGMENTED REALITY NAVIGATION

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Abstract: This work deals with an application of the augmented reality in navigation devices. It describes possibilities of the video processing, rendering a virtual scene by using data measured by satellite and inertial navigation subsystems. A special care is taken into account for use of a modern graphic accelerator hardware available in microprocessors. The design of the application is supplemented with a prototype realization.

Keywords: Augmented reality, satellite navigation, inertial measurement unit

1. PREFACE

Main goal of this project [1] [2] is to develop a device capable of rendering a real time overlay over the captured video frame. There are three external inputs, the image sensor capable of video capture feeds real-time images to the system. The GPS receiver delivers positional information and inertial sensors supplement it with spatial orientation. Expected setup is that the image and inertial sensors are on a single rack able to freely rotate around, while the GPS receiver is static, relative to the whole moving platform. The overlay consists of fixed kinematic data such as speed or altitude, reference indicators such a horizon line and dynamic location markers. These will be spatially aligned with real locations visible in the video thus providing navigation information. They work in a way that wherever the camera is pointed to, specific landmarks will label currently visible locations. Complex external navigation system may be also connected. This allows integration with already existing systems, such as moving map systems, PDAs or other specialized hardware. These provides user with classic route navigation and map projection, while this project gives spatial extension to further improve total situational awareness. This work focuses on visual enhancement instead of a full featured navigation device. Overview on of the project design is in the following figure.

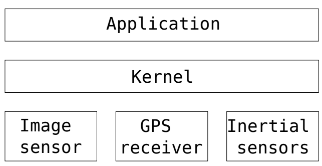

Figure 1: Project overview.

The application runs on top of the embedded Linux kernel which has been chosen to provide a common interface for the hardware abstraction and system level libraries. The application itself is divided into four subsystems, each being a standalone component.

2. VIDEO AND GRAPHICS SUBSYSTEM

The video subsystem provides a common interface for an external image sensor and feeds captured video frames to the rendering loop. V4L2 device driver is used to provide the hardware abstraction, while the application handles format negotiation and memory management. Memory mapping is used to pass video frames between the application and the kernel, a texture streaming extension is used to further push these buffers to the GPU, which then handles the YUV to RGB color-space conversion. This design ensures that the data itself are always passed by pointer without any copying.

The graphics subsystem handles rendering of the overlay, it creates the actual output of the device. OpenGL ES 2.0 library has been chosen to provide a hardware abstraction for the graphical processing unit. The application controls the rendering pipeline, while the GPU does the actual vertex and fragment processing. The overlay consists of objects, these objects are composed of predefined geometry primitives and pre-rasterized glyphs using the FreeType library. The composition is done in real-time. The image below shows the simplified output rendered by the application. In the top left corner is the current speed over the ground, while in the top right corner is the current altitude above a mean sea level. In the top center is the current waypoint name and distance. There is a heading ruler in the bottom, it is scaled by camera field of view and oriented to the current heading. The course to any visible object may be deducted directly from the ruler. There are two markers, the arrow marker shows the current track angle, the circle marker shows a course to the current waypoint. The dashed horizontal line in the center of the image is the horizon line. The *testA* landmark label is visible in the image, its location is centered directly above its projection. Projections are calculated in conjunction of both navigation subsystems. External landmark database is supplemented to provide spatial navigation references.

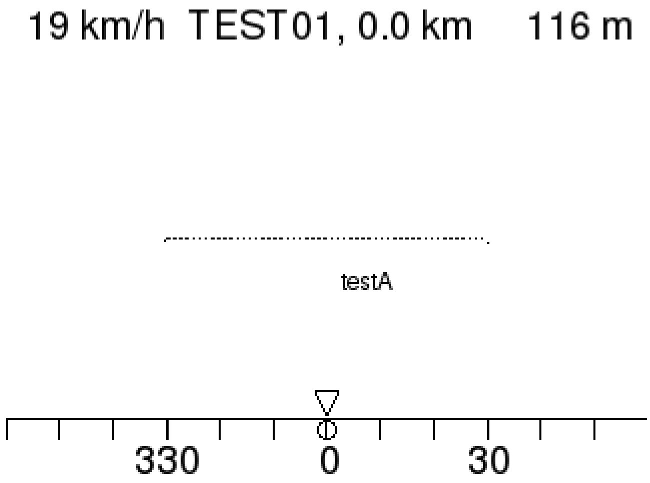

Figure 2: Visible output.

3. INERTIAL MEASUREMENT AND SATELLITE NAVIGATION SUBSYSTEMS

The inertial measurement subsystem implements a directional cosine matrix algorithm to calculate device attitude. This matrix is calculated by applying consecutive rotations by gyroscope angular displacement angles and filtering with accelerometer and magnetometer vectors. Several iterations are done per each video frame to provide reliable attitude information with good stability and dynamic response. Industrial I/O kernel module is used to provide hardware abstraction for the embedded digital gyroscope, accelerometer and magnetometer.

The satellite navigation subsystem handles connection with the external GPS receiver over the serial interface. It provides NMEA 0183 protocol parser and mathematical model for the WGS84 reference ellipsoid. Interpolated positional and kinematic output is calculated for each rendering loop as most GPS receivers have relatively long fix period.

The projection angles for the landmark labels are computed as

$$\alpha_{proj} = \arctan\left(\frac{\sin(\lambda-\lambda_0)\cos(\varphi)}{\cos(\varphi_0)\sin(\varphi) - \sin(\varphi_0)\cos(\varphi)\cos(\lambda-\lambda_0)}\right) \quad ,$$

$$\beta_{proj} = \arcsin\left(\frac{b_\Delta}{c_\Delta}\sin(\phi)\right) - \frac{\pi}{2} \quad ,$$

where φ is geodetic latitude and λ longitude (zero index denotes device's own values), Φ is the angular distance defined as

$$\phi = \arccos(\sin(\varphi_0)\sin(\varphi) + \cos(\varphi_0)\cos(\varphi)\cos(\lambda - \lambda_0))$$

and a_Δ, b_Δ, c_Δ are sides of a triangle connecting a center of the reference ellipsoid, the device and the landmark position respectively

$$a_\Delta = h_0 + R_{(\varphi_0)}, \quad b_\Delta = h + R_{(\varphi_0)}, \quad c_\Delta = \sqrt{a_\Delta^2 + b_\Delta^2 - 2 a_\Delta b_\Delta \cos(\phi)} \quad ,$$

where h is the height above the reference ellipsoid and R is the ellipsoid radius at the given latitude.

4. REFERENCE HARDWARE IMPLEMENTATION

Following schematic shows the proposed hardware design. Texas Instruments OMAP application microprocessor [3] was chosen for the reference implementation. MPU-9150 is an embedded motion tracking device composed of a digital gyroscope, an accelerometer and a magnetometer with I2C interface. Serial embedded camera or possibly external camera may be used for video capture, video output is available via internal HDMI interface to any compatible display. External serial connection is provided for satellite navigation receiver, any NMEA 0183 compatible device may be used. Whole system is portable with low-power battery supply.

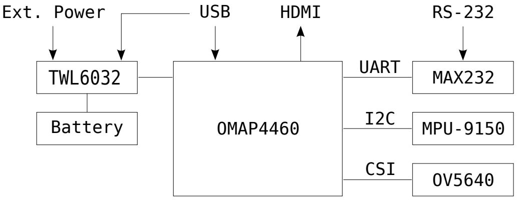

Figure 3: Hardware design.

5. CONCLUSION

Functional application has been implemented and a 1080p video quality has been achieved with the prototype. Hardware video acceleration of the OMAP platform has been successfully used to stream video in H.264 encoding in addition to the raw format. Practical tests are still ongoing to determine applicable end-user use-cases. The application proved to be robust, portable and modular enough to provide basis for further developments of augmented reality navigation devices.

REFERENCES

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