Synchron – An API and Runtime for Embedded Systems (Artifact)

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Abstract

Programming embedded applications involves writing concurrent, event-driven and timing-aware programs. Traditionally, such programs are written in machine-oriented programming languages like C or Assembly. We present an alternative by introducing Synchron, an API that offers high-level abstractions to the programmer while supporting the low-level infrastructure in an associated runtime system and one-time-effort drivers.

Embedded systems applications exhibit the general characteristics of being (i) concurrent, (ii) I/O–bound and (iii) timing-aware. To address each of these concerns, the Synchron API consists of three components - (1) a Concurrent ML (CML) inspired message-passing concurrency model, (2) a message-passing–based I/O interface that translates between low-level interrupt based and memory-mapped peripherals, and (3) a timing operator, `syncT`, that marries CML's `sync` operator with timing windows inspired from the TinyTimber kernel.

We implement the Synchron API as the bytecode instructions of a virtual machine called SynchronVM. SynchronVM hosts a Caml-inspired functional language as its frontend language, and the backend of the VM supports the STM32F4 and NRF52 microcontrollers, with RAM in the order of hundreds of kilobytes. We illustrate the expressiveness of the Synchron API by showing examples of expressing state machines commonly found in embedded systems. The timing functionality is demonstrated through a music programming exercise. Finally, we provide benchmarks on the response time, jitter rates, memory, and power usage of the SynchronVM.

1 Scope

The paper describes the design, implementation and APIs of a virtual machine called SynchronVM. The artifact presents concrete evidence of the implementation of the virtual machine and shows all of the programs presented in the paper running on top of SynchronVM. All of the code-listings presented in the paper are presented within this artifact and are runnable using SynchronVM.

2   Content

The artifact package includes:
- A virtual machine image titled `sensevm.ova` that has all the software preloaded and installed for demonstration.
- Videos showing how to run the various code listing.
- A copy of the SynchronVM codebase.
- A copy of the ScriptableTester codebase that has been used to measure the response time for the `button-blinky` program.

3   Getting the artifact

The artifact endorsed by the Artifact Evaluation Committee is available free of charge on the Dagstuhl Research Online Publication Server (DROPS). In addition, the artifact is also available at: `https://chalmersuniversity.box.com/s/g1r0jxra1lcd69u5455s3lwjfcx05re1`.

The SynchronVM codebase is an MIT Licensed open sourced repository under active development. It can be found here – `https://github.com/SynchronVM/SynchronVM`

4   Tested platforms

The virtual machine image should be portable for Linux, MacOS and Windows based operating systems.

Special hardware is required if the reader wants to run the programs on microcontrollers. We use two microcontroller platforms for our experiments –
- STM32F407G-DISC1 -the "STM discovery board"
- NRF52840-DK - Nordic Semiconductor microcontroller development board

5   License

The artifact is available under the MIT license.

6   MD5 sum of the artifact

abe95282c41b33b10a394d0171bebcdd

7   Size of the artifact

9.6 GiB