Csound 6, Old Code Renewed

LAC2013

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Introduction

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Moving to a new version allowed developers to rethink key aspects of the system, without the requirement of keeping ABI or API compatibility with earlier iterations.

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A Short History of Csound

Csound can be traced back to Barry Vercoe's MUSIC 360 package for computer music (1968), which was itself a variant of Max Mathews' and Joan Miller's MUSIC IV (1964).

Following the introduction of the PDP-11 minicomputer, a modified version of the software appeared as MUSIC 11.

Later, with the availability of C (and UNIX), this program was re-written in that language as Csound, allowing a simpler cycle of development and portability, in comparison to its predecessor. In the early 2000s, the final releases of version 4 attempted to retrofit an application programming interface (API), so that the system could be used as a library.

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Csound 5

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Much of this development included updating 1970s programming practices by applying more modern standards. One of the major aims was to make the code reentrant, so that its use as a library could be made more robust.

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Csound operation in a nutshell

As a MUSIC-N language, Csound incorporates a compiler for instruments. During performance, these can be activated (instantiated) by various means, the traditional one being the standard numeric score.

The steps involved in the compiler can be divided into two: parsing, and compilation proper.

At instantiation, an init-pass loop is performed, executing all the once-off operations for that instance. This is then inserted in a list of active instruments, and its performance code is executed sequentially, processing vectors (audio signals), scalars (control signals) or frames of spectral data.

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Motivation

Following the 2011 Csound Conference in Hannover, there were a number of user requests that would be more easily achievable with a version bump:

- the capacity of new orchestra code, ie. instruments and user-defined opcodes (UDOs), to be added to a running instance of the engine
- additions to the orchestra language, for instance, generic arrays
- rationalisation of the API to allow further features in frontends
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Developments to date: Build system and Tests

In Csound 6, the official build system is now the CMake-based build. Moving to CMake introduced some hurdles and changes in workflow, but it also brought with it generation of build system files, such as Makefiles, XCode projects, and Eclipse projects.

Unit and functional tests have been added to Csound 6's codebase. CTest is the test running utility used to execute the individual C-code tests. In addition, CUnit is employed to create the individual tests and test-suites within the test code files. Beyond C-code testing, the suite of CSD's used for application/integration testing continues to grow, and a new set of Python tests has also been added for testing API usage from a host language.

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Developments to date: Code Reorganisation

The Csound code base is passing through a significant reorganisation:

- obsolete code, such as the old parser, has been removed.
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- The CSOUND struct has been rationalised and reorganised
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Developments to date: Type System

The Csound language uses strongly typed variables and enforces these at compile-time. The system of types was hard-coded into the parser and compiler.

In Csound 6, a generic type system was implemented as well as tracking of variable names to types. The new system provides a mechanism to create and handle types, such that new types can be easily added to the language.

Variable definitions and types are kept after compilation. This allows the possibility of inspecting variables found in instruments or in the global memory space.

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In Csound 5, a ‘t’ type was added that provided a user-definable length, single-dimension array of floating-point numbers.

In Csound 6, with the introduction of the generic type system, the code for t-types was extended to allow creation of homogenous, multi-dimensional arrays of any type. Additionally, the argument list specification for opcodes was extended to allow denoting arrays as arguments.

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Developments to date: On-the-fly Compilation

The first steps necessary for on-the-fly compilation, were in the latter versions of Csound 5, with the introduction of the new parser. Also, compilation from text files was replaced by a new core (memory) file subsystem, so now strings containing Csound code could be presented directly to the parser.

In Csound 6, the monolithic API call to compile/start Csound is broken down into `csoundParseOrc()` + `csoundCompileTree()` (with these two combined in `csoundCompileOrc()`) and `csoundStart()`. The parsing function creates an abstract syntax tree (AST) from a string containing Csound code. The compilation function then creates the internal data structures that the AST represents, ready for engine instantiation. These operations can be performed repeatedly.

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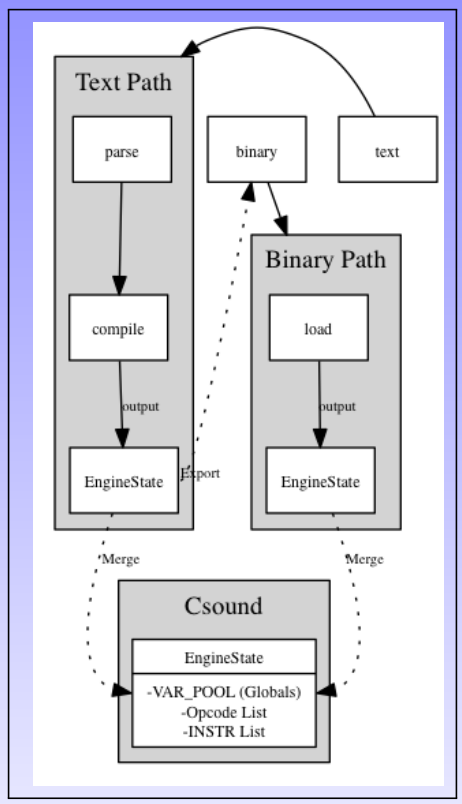

Developments to date: Sample Accuracy

Csound has always allowed sample-level accuracy, a feature present since its MUSIC 11 incarnation, by setting the processing block, (`ksmps`), to 1 sample.

In Csound 6, an alternative sample accuracy method has been introduced, using an offset into the processing block, which will round the start time of an event to a single sample. Similarly, event durations are also made to be sample accurate, as the last iteration of each processing loop is limited to the correct number of samples.

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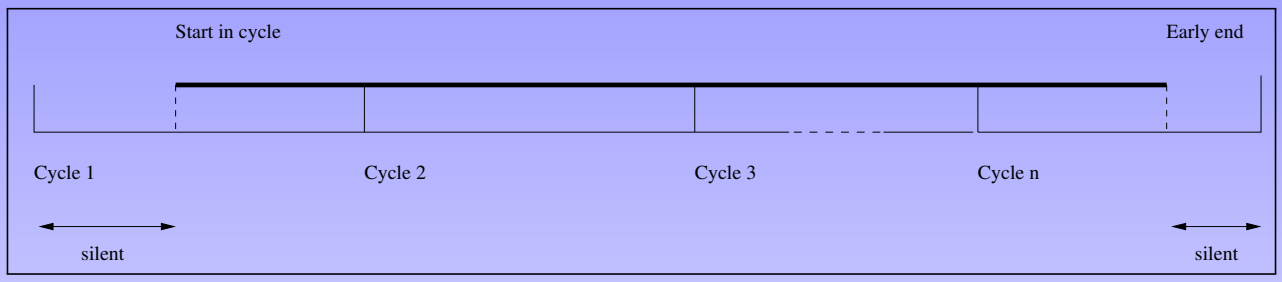

This option is provided with the non-default `--sample-accurate` flag, to preserve backward compatibility.

Developments to date: Realtime Priority Mode

Csound has been a realtime audio synthesis engine since 1990, although it was never provided with strict realtime-safe behaviour.

Given the multiple applications of Csound, it makes sense to provide separate operation modes for its engine. In Csound 6, we introduce the realtime priority mode, set by the `--realtime` option, which aims to provide better support for realtime safety, with complete asynchronous file access and a separate thread for unit generator initialisation.

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Developments to date: Multicore Operation

In 2009 an experimental system for using multiple cores for parallel rendering of instruments was written, and later incorporated in Csound 5. While the design was generally semantically correct it only delivered moderate performance gains.

For Csound 6 we are developing a different approach, where semantic analysis and the creation/consumption of the DAG of dependencies is only done on instantiation/destruction of instruments. This uses watch-lists as found in SAT-solvers.

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Developments to date: Multicore Operation, preliminary results

-j	CloudStrata	Xanadu		Trapped...		
	ksmps=500 (sr=96000)	ksmps=10	ksmps=100	ksmps=10	ksmps=100	ksmps=1000
1	1	1	1	1	1	1
2	0.54	0.57	0.55	0.75	0.79	0.78
3	0.39	0.40	0.40	0.66	0.76	0.73
4	0.32	0.39	0.33	0.61	0.72	0.70

Relative performance with multiple threads in three existing Csound code examples, -j indicates the number of threads used

Other developments

Since the time of the writing of this paper, other developments have taken place:

- Reordering of compilation stages and overhaul of the semantic system.
- support for functions with more than one arguments and opcodes as functions (that can be inlined in expressions) was added.

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- multiple strings in event parameters are now allowed
- support for array operations has been added
- the 6.00 API has been finalised
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Third-party frontend example

(example)

Cabbage Live Coder frontend by Rory Walsh

Future developments

A number of ideas have also been put forward, which will be tackled in due course. These include for instance:

- support for alternative orchestra languages (through access to the parse tree format or some sort of intermediary representation) and programmatic building/editing of instruments.
- further language features (e.g. namespaces, tuples, block scoping, dynamic typing)
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