supernova - A Multiprocessor Aware Real-Time Audio Synthesis Engine For SuperCollider

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Outline

SuperCollider

- **sclang**, a real-time scripting language, with a huge class library
- **scsynth**, an audio synthesis engine
- a huge number of unit generators, provided as plugins
- a gui system (with 2 implementations)
- several IDEs

supernova

- a multi-processor aware replacement for scsynth
- exposes parallelism to the user of the language
- designed for low-latency real-time applications

Parallelism

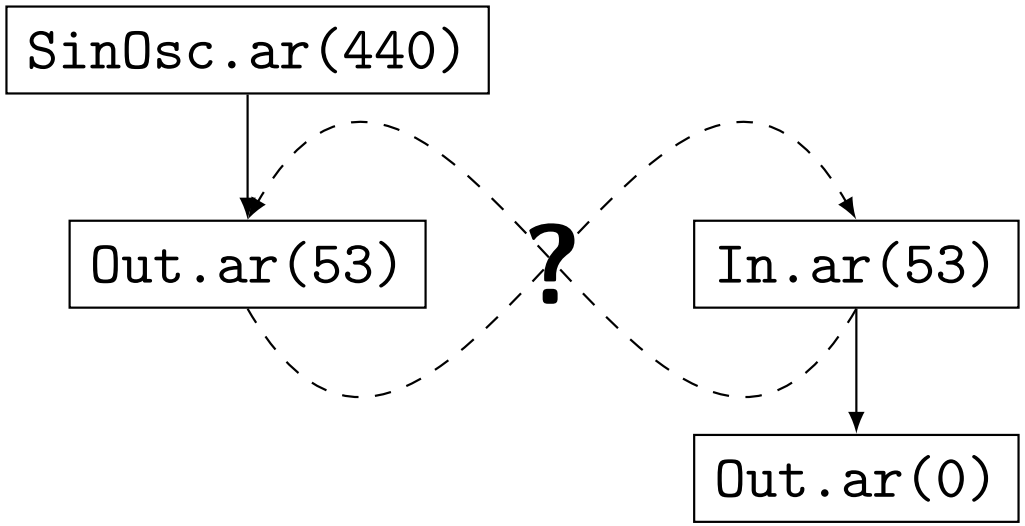
- channels
- voices, polyphonic music
- tracks/buses
- additive synthesis
- ...

Signal Graph Parallelism

- What is the size of the synthesis graph?
- How big are the CPU expenses of the nodes?
- Graph nodes can be combined to avoid scheduling overhead.

Node Dependencies

- There may be implicit dependencies based on resource access!
- A dependency analysis may not be trivial
- Automatic dependency analysis may be difficult or impractical to implement



Real-Time Node Scheduling

- How can the node graph be traversed in a real-time context?
- Deadlines are almost one milliseconds (64 samples)!
- Scheduling latency may be hundreds of microseconds (unless we are on highly tuned hardware with RT preemption patches).
- Avoid locks!

SuperCollider Node Graph

- SuperCollider uses **groups** for structuring the audio synthesis
- Groups are linked lists of **nodes**
- Nodes can be groups or **synths**.

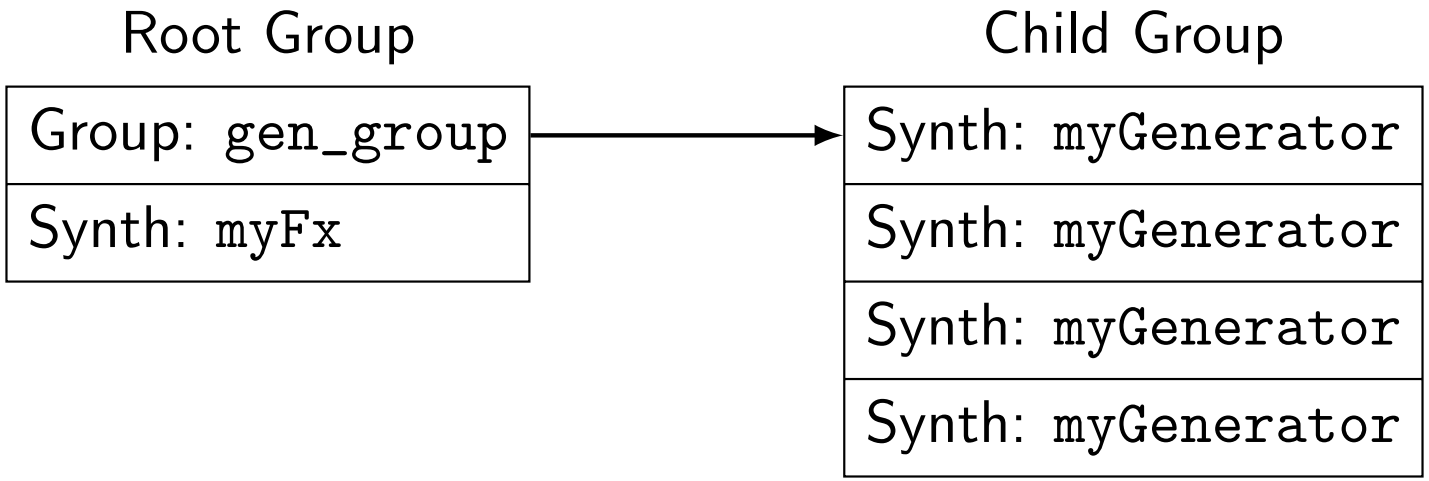
Groups - Features

- Form a tree hierarchy with a group as root
- Syntactic sugar for organizing the audio synthesis
- Multiple nodes can be addressed as one entity
- Expose the order of execution explicitly to the user

Groups - An Example

```
var gen_group, fx;
gen_group = Group.new;
4.do {
    Synth.head(gen_group, \myGenerator)
};
fx = Synth.after(gen_group, \myFx);
```

Groups - An Example (2)



Parallel Groups

How to introduce parallelism to concept of the SuperCollider node graph?

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Parallel Groups

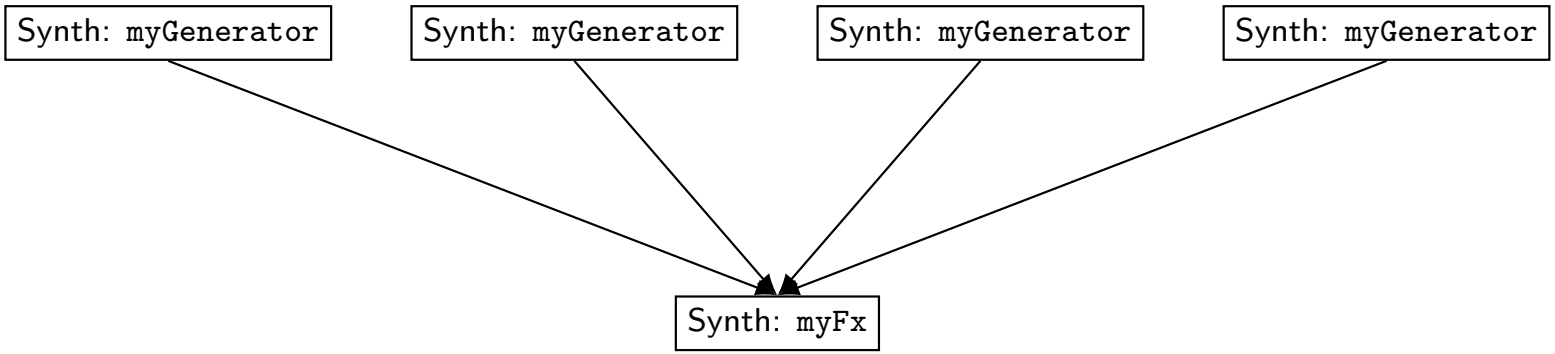
Parallel Groups

- Semantics similar to groups
- Nodes can be executed in parallel
- Integrates well into the SuperCollider node graph:
  One more class, one more OSC command for the server
- Backward compatible: Old code still keeps its semantics
- Forward compatible: Parallel groups can easily be emulated with groups

Parallel Groups - An Example

```
var gen_group, fx;
gen_group = PGroup.new;
4.do {
    Synth.head(gen_group, \myGenerator)
};
fx = Synth.after(gen_group, \myFx);
```

Parallel Groups - An Example (2)



Architecture of supernova: Features

- Focuses on latency instead on throughput
- No pipelining, so no additional latency
- Mostly lock-free synchronization (boost.lockfree)
- SC node graph needs to be transferred into a dependency graph representation.

Architecture of supernova: Issues

- Idle threads perform busy waiting (produces heat, takes resources)
- No automatic dependency checking
- Some use cases may be difficult to formulate to get the best performance
- ... and no non-rt synthesis (yet)

SuperCollider Unit Generators

- Supernova can load SuperCollider Unit Generators
- Unit generators need to be adapted to ensure data consistency
- All unit generators from the SuperCollider distribution have been ported to supernova
- Some unit generators from the sc3-plugins as well

Resource Consistency

- Reader-writer spinlocks are used to ensure data consistency
- Reading the same resource from parallel synths is safe
- Writing to the same resource from parallel synths may be safe:
  `Out.ar` is safe
  `ReplaceOut.ar` is not
- Writing to the same resource from parallel synths increases contention!

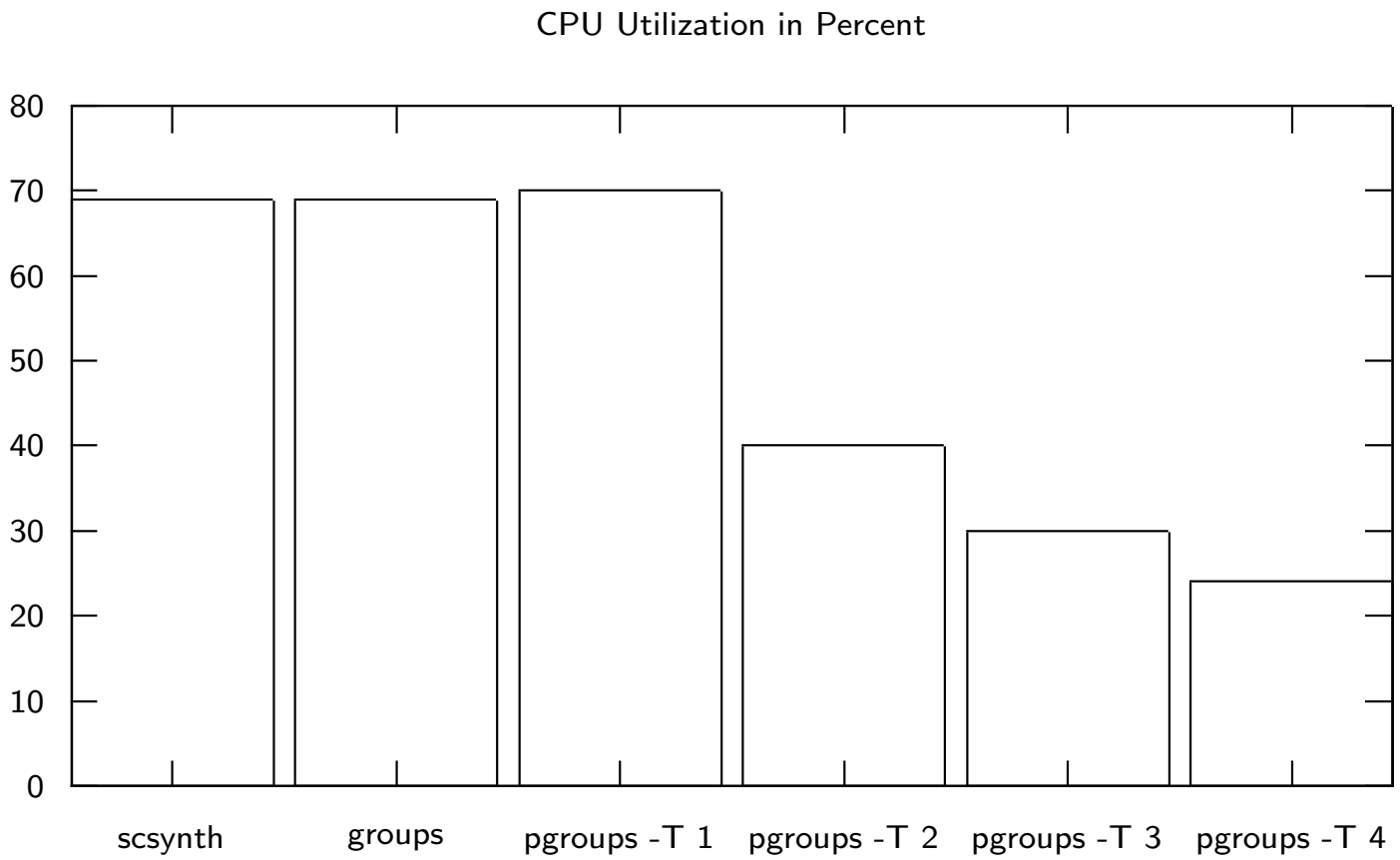
SuperCollider Unit Generators: An Example

```
void In_next_a(IOUnit *unit, int inNumSamples)
{
    [...]

    for (int i=0; i<numChannels; ++i,
         in += bufLength) {


        if (touched[i] == bufCounter)
            Copy(inNumSamples, OUT(i), in);
        else
            Fill(inNumSamples, OUT(i), 0.f);

    }
}
```

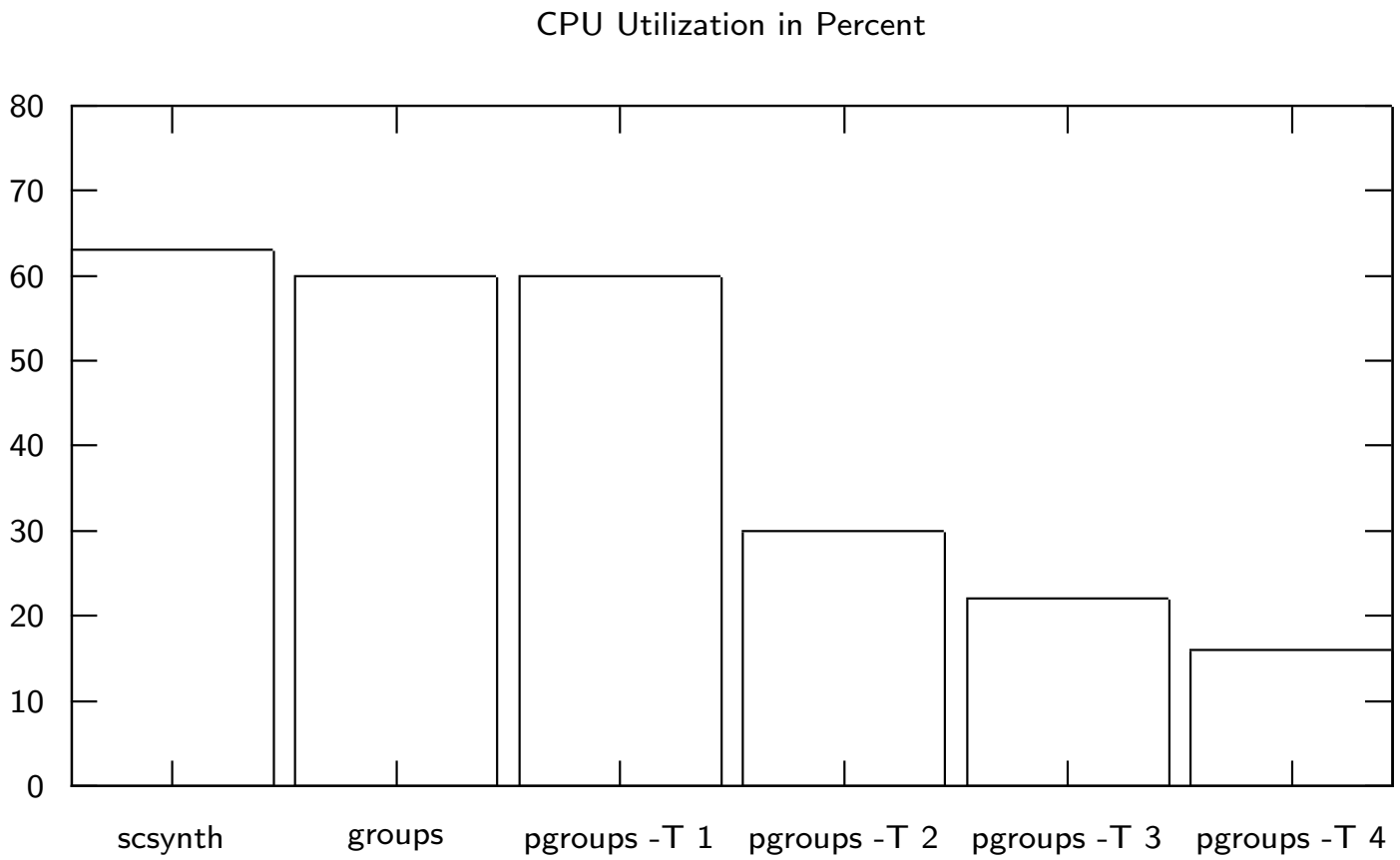
SuperCollider Unit Generators: An Example

```
void In_next_a(IOUnit *unit, int inNumSamples)
{
    [...]

    for (int i=0; i<numChannels; ++i,
         in += bufLength) {
        int32 busChannel = (int32)fbusChannel + i;
        ACQUIRE_BUS_AUDIO_SHARED(busChannel);
        if (touched[i] == bufCounter)
            Copy(inNumSamples, OUT(i), in);
        else
            Fill(inNumSamples, OUT(i), 0.f);
        RELEASE_BUS_AUDIO_SHARED(busChannel);
    }
}
```

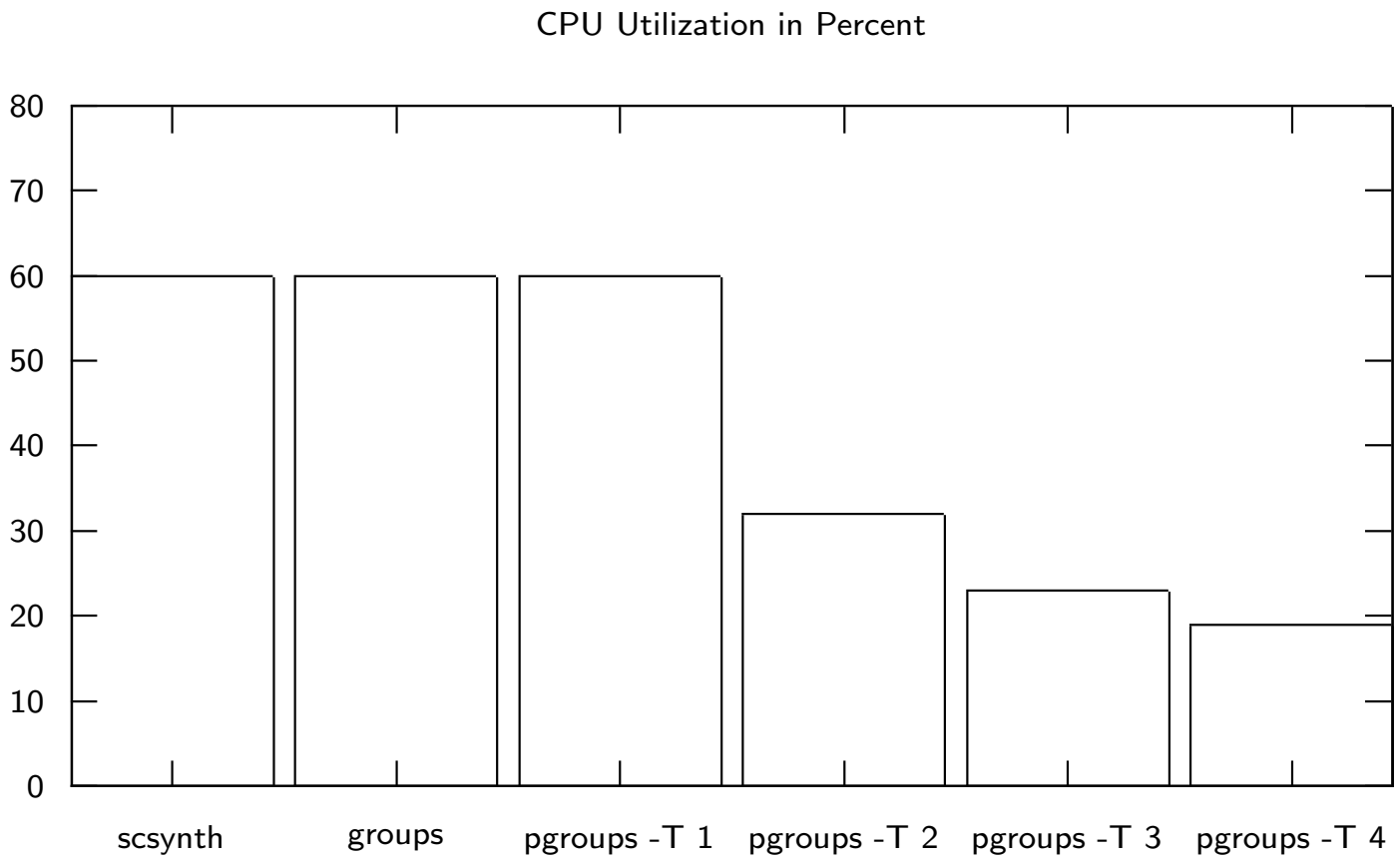
1024 Lightweight Synths



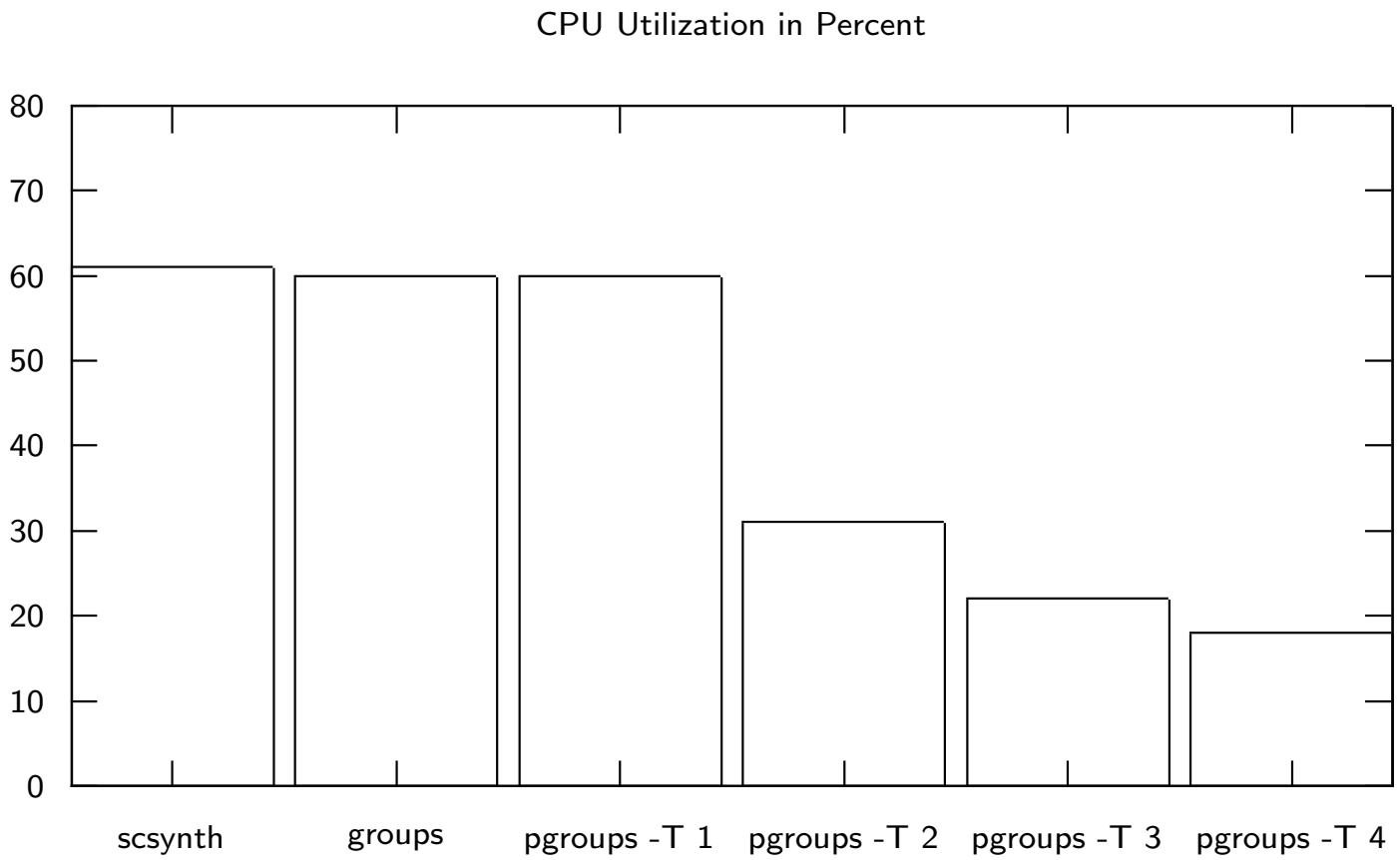
30 Heavyweight Synths



128 Synths with High Resource Contention



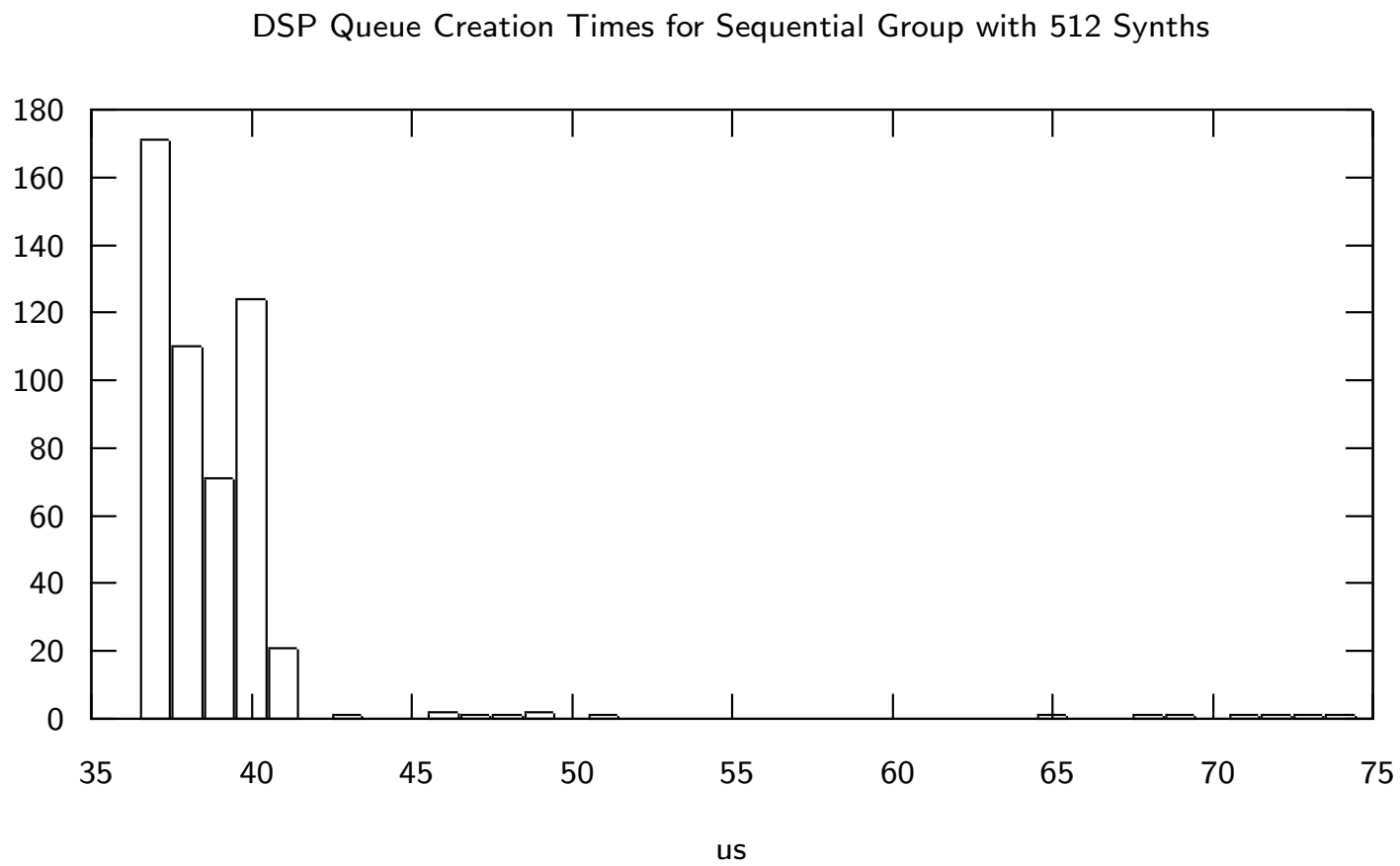
128 Synths with Low Resource Contention



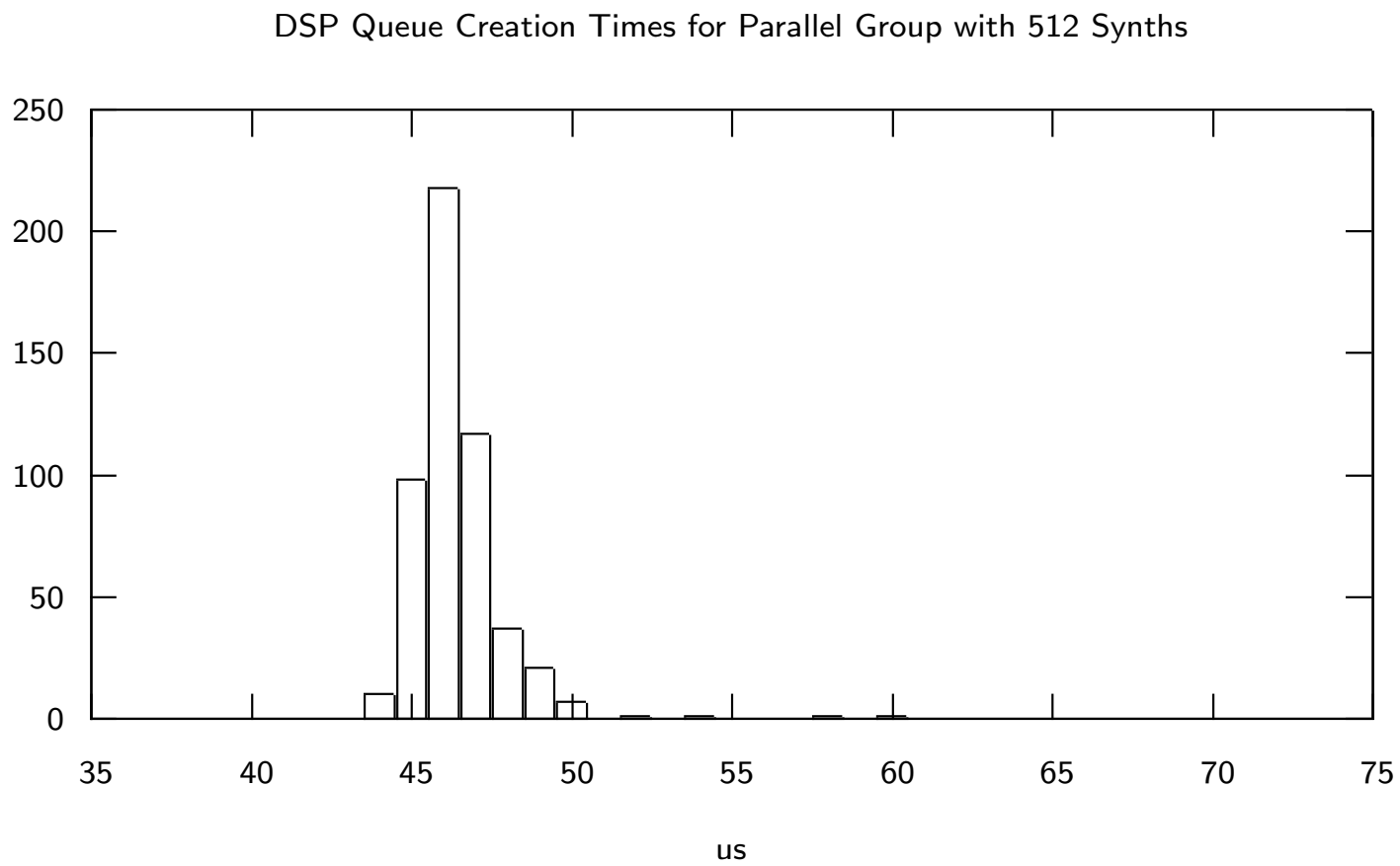
Speedup Overview

	Small Synths	Large Synths	High Contention	Low Contention
scsynth	1	0.95	1	0.98
sequential groups	1	1	1	1
parallel groups, 1 thread	0.98	1	1	1
parallel groups, 2 threads	1.72	2	1.87	1.94
parallel groups, 3 threads	2.33	2.73	2.61	2.73
parallel groups, 4 threads	2.88	3.75	3.16	3.33

Node Graph Parsing, Group



Node Graph Parsing, Parallel Group



Summary

- supernova is a drop-in replacement for scsynth
- supernova extends the SuperCollider node graph by a simple concept
- not a single crash during a concert

Conclusion

Thanks!
Questions?