# Csound Opcodes for Scanned Synthesis

Scanned synthesis is a variant of physical modeling, where a network of masses connected by springs is used to generate a dynamic waveform. The opcode *scanu* defines the mass/spring network and sets it in motion. The opcode *scans* follows a predefined path (trajectory) around the network and outputs the dynamic waveform. Several *scans* instances may follow different paths around the same network.

These are highly efficient mechanical modeling algorithms for both synthesis and sonic animation via algorithmic processing. They should run in real-time. Thus, the output is useful either directly as audio, or as controller values for other parameters.

Please note that the generated dynamic wavetables are very unstable. Certain values for masses, centering, damping can cause the system to "blow up" and the most "interesting" sounds to emerge from your loudspeakers...

## SCANU

The syntax for *scanu* is:

```
        scanu     init, irate, ifnvel, ifnmass, ifnstif, ifncentr, ifndamp, kmass, kstif, \
                     kcentr, kdamp, ileft, iright, kx, ky, ain, idisp, id
```

*init*: The initial position of the masses. If this is a negative number, then the absolute of *init* signifies the table to use as a hammer shape. If *init* > 0, the length of it should be the same as the number of masses (128), otherwise it can be anything.

*irate*: The amount of time between successive updates of the mass state. Kind of like the sample period of the system. If the number is big the string will update at a slow rate showing little timbral variability, otherwise it will change rapidly resulting in a more dynamic sound.

*ifnvel*: The number of the ftable that contains the initial velocity for each mass. It should have the same size as the number of masses (128).

*ifnmass*: The number of the ftable that contains the mass of each mass. It should have the same size as the number of masses (128).

*ifnstif*: The number of the ftable that contains the spring stiffness of each connection. It should have the same size as the square of the number of masses (16384). The data ordering is a row after row dump of the connection matrix of the system.

*ifncentr*: The number of the ftable that contains the centering force of each mass. It should have the same size as the number of masses (128).

*ifndamp*: The number of the ftable that contains the damping factor of each mass. It should have the same size as the number of masses (128).

*kmass*: Scales the masses.

*kstif*: Scales the spring stiffness.

*kcentr*: Scales the centering force.

*kdamp*: Scales the damping.

*ileft*: If init < 0, the position of the left hammer (*ileft* = 0 is hit at leftmost, *ileft* = 1 is hit at rightmost).

*iright*: If init < 0, the position of the right hammer (*iright* = 0 is hit at leftmost, *iright* = 1 is hit at rightmost).

*kx*: The position of an active hammer along the string (0 leftmost,1 rightmost). The shape of the hammer is determined by *init*. The power it pushes with is *ky*.

*ky*: The power that the active hammer uses.

*ain*: The audio input that adds to the velocity of the masses.

*idisp*: If 0 then there is no display. If 1 then display the dynamic evolution of the masses.

*id:* The ID of the opcode. This will be used to point the scanning opcode (*scans*) to the proper waveform maker. If this value is negative, it indicates the wavetable on which to write the waveshape. That wavetable can be used later from another opcode to generate sound. Note: The initial contents of this table will be destroyed, so don’t rely on them being there.

## SCANS

The syntax for scans is:

ar **scans** kamp, kfreq, ifntraj, id[, korder]

*kamp*: The output amplitude. Note that the resulting amplitude is also dependent to the state of the wavetable.

*kfreq*: The frequency of the scan rate.

*ifntraj*: The number of the ftable that contains the scanning trajectory. This is a series of numbers that contains addresses of masses - the order of these addresses is used as the scan path. It shouldn't contain more values than the number of masses (128), and it should not contain negative numbers.

*id*: The ID number of the *scanu* waveform to use.

*korder*: The order of interpolation used internally. It can take any value in the range 1 to 4, and defaults to 4, which is quartic interpolation. 2 is quadratic and 1 is linear. The higher numbers are slower, but not necessarily better.

## MATRICES

To produce the matrices, the file format is straightforward. For example, for 4 masses we would have the following grid describing the connections:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

Whenever two masses are connected then the point they define is 1, so for a unidirectional string we would have the following connections, (1,2), (2,3), (3,4) (if it was bi-directional we would also have (2,1), (3,2), (4,3)). So we fill these out with ones and the rest with zeros and we get:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 0 |
| 2 | 0 | 0 | 1 | 0 |
| 3 | 0 | 0 | 0 | 1 |
| 4 | 0 | 0 | 0 | 0 |

Similarly for the other shapes, we find the connections and fill them out. This gets saved in an ASCII file, column by column. Thus, the string shown above would be saved as:

```
0.
1.
0.
0.
0.
0.
1.
0.
0.
0.
0.
1.
0.
0.
0.
0.
```

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