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MODULAR FEEDBACK KEYBOARD

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ABSTRACT : The MODULAR FEEDBACK KEYBOARD that we are going to describe here was brought out in October 1988 and its construction is the result of research of many years in our laboratory on the *instrumental relationship* within the framework of real-time sound synthesis and computer assisted musical creation. An international patent covers both its modularity principle as well as its motor technology, that was specially developed for the keyboard performance. In the first instance this device is a *feedback* gestual control organ for the tactile senses, that is, it enables actual fingering of the instrument to be synthesised. But it is also a *modular* system : the piano or organ type keyboard is its nominal form, but its mechanical morphology can be modified and easily configured for other applications.

Mechanical feedback - Touch synthesis, instrument simulation, and the instrumental relation.

We introduced the "tactile feedback" principle, by building a first experimental device in 1978. By producing a mechanical feedback force on the very same level as the manipulation organ, this device enabled a "touch synthesis" to be obtained. The result was simultaneous to and coherent with the sound and, if required, with the visual display of the instruments concerned. We were not simply aiming at improved ergonomoy of gestual control in sound synthesis, but rather at a fundamentally new insight into musical synthesis itself : our approach focussed on the importance of the instrumental relation in both the learning and the intrinsic process of musical creation. We therefore were led to propose not only a synthesis of the sound but also of the *instrument*.

The device that liaises the relation between gestual and numeric phenomena, is, in computer synthesis, the gestual transducer. Hence, it has a very special role for : 1. The instrumental gesture must be made in a genuine manner : by definition the instrumental gesture is applied to a physical object that has typical and determined deformation and displacement possibilities. 2. It must sense the characteristic information of the gesture without reduction. 3. Finally, it has to provide the instrumentalist with a mechanical resistance, in function of the nature of the simulated generator process. This third function is what we shall refer to here as FEEDBACK. It is fundamental to control finesse.

It therefore follows that our device for genuine instrumental play, in addition to the usual control actions, be they in real- or non real- time, *must include motor organs, that are in fact the "transmitters" of the physical phenomenon that is responsible for the tactile perception.*

It goes without saying that such motors must be special. Their performance entails ultra-rapid, and accurate "response", (in some cases the bandwidth of the mechanical phenomena concerned in the gesture can go as far as 700 or 800 Hz), sizable power (up to pulses of several tenths of KgF to simulate rigid obstacles), and, moreover, be packed away in a very confined space.

Classical electric motors cannot offer these three characteristics simultaneously, and this is why we have designed a special motor that can provide sufficient power and is about the size of a standard piano key.

Modularity

A transducer for the gestual channel as general as a loud speaker is to the acoustic channel is not foreseeably possible, given the current state of the technology. Because of this, the instrumental interface device can only be presented as a *system of different and complementary devices*.

The above remark therefore induced us to investigate what kind of device would guarantee us a relative variety of instrumental situations and yet still uphold a keyboard conception according to its traditional characteristics.

Modularity features two aspects : It allows for freedom of choice as to the number of "keys" (in fact, the number of degrees of freedom), and offers a choice of morphology.

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(By *morphology* we mean everything that characterises the outside shape, the trajectories, and the geometric and spatial constraints of the manipulated physical organ. This also determines the types of prehension and contact as well as the possible types of gestures).

The complete device is built from two basic components : the Sensor/Motor module and the "packaging". Both respectively allow for the two types of modularity.

The Sensor / Motor module

As its name suggests it takes charge of the two functions, that are integrated in the same organ. But, we might say that its role is precisely only to fulfill these two functions, i.e. according to strictly defined basic characteristics. It must :

1. Measure displacement according to a degree of liberty, and supply an electric image of this.
2. Produce a force that is proportional to a command, across a given displacement range following the same degree of liberty.

Its most noteworthy property is its geometry : To meet the first bulk constraint - which was not to be thicker than a single piano key (13.75 mm) and still produce sufficient power - we had to think in terms of special technology. The result was what we call the "*sliced motor*" (patented).

The sliced motor

The principle consists in creating a single magnetic polarisation circuit (in this instance rectilinear) for all the motor modules. The latter are independent and are designed to be combinable into a single system. -

The system when set up is thus composed of an alternant series of polarisation magnets and flat mobile coils (fig. 1). Each addition to the whole is done by adding a mechanically autonomous "slice", composed of a magnet-coil pair and then closing off the magnetic circuit by means of a "sealer module". Modularity is assured because the forces produced by the coils are completely independent from each other. The power is obtained thanks to the combination of the magnetic fields of each module.

Motor/Sensor module characteristics :

Geometric : mobile motor coil stroke 15 mm. Sensor : position sensor LVDT, res. app. 3 μm .

Motor : - Slice thickness 13.75 mm,- flat copper mobile coils vacuum soaked (mass 200 gr), rare earth / cobalt magnets, effective induction 0.65 T, - friction < 9.10⁻³N, - Maximal permanent force 40N, - Maximal transitory force 80N, - Maximal acceleration off-load 660 m/s², - Response delay to the input control, (movement blocked) 0.2 ms.

"Covering"

The device's effective morphology is determined by the association of a certain number of Sensor/Motor modules and the "Covering" that is given to the whole. This covering consists of a very simple and strongly built mechanical device chosen from an "assortment" of various possibilities which is mounted onto the Motor/Sensor bank.

We shall illustrate this principle of interchangeable covering by three examples :

Keyboard (fig. 3.1) : The key arms (which, incidentally can be permanently mounted on the base module) enable us to receive different plates which correspond to the various keys of a regular keyboard. The position of the black keys and the white keys can therefore be respected, but this can also be completely arbitrary, since the rest position height can be controlled by program.

1D and 2D Joy-sticks : A mechanically connected transmission arm (that clicks into the place of the previous key plates) allows us to use one module as a 1D device (fig. 3.2) or to combine two independent Sensor/Motor modules to create a system with two degrees of liberty (fig. 3.3).

A similar device allows combination of three degrees of liberty in the same manner. It can thus be seen that modularity can effect liberty degree combination possibilities to make up one or several simple or multidimensional sets.

This device is currently used in our laboratory for a certain number of experiments in musical synthesis. It is also used for animation of synthesized images. Since the introduction of feedback force in its present high performance version (in particular in the context of synthesis derived from physical models) it has turned out that this is not simply a "plus" in the accuracy and richness of control, but has opened up a genuine new dimension in the Man/Machine relation for animated image synthesis. In the sphere of artistic, musical, or graphic creation, it is patently clear that this is fundamental and promising for the future. We should also point out that very principle of the T.G.R. and the implementation of the "instrumental situation" that we are referring to here, seem to be interesting for numerous other fields and will probably be generalised.

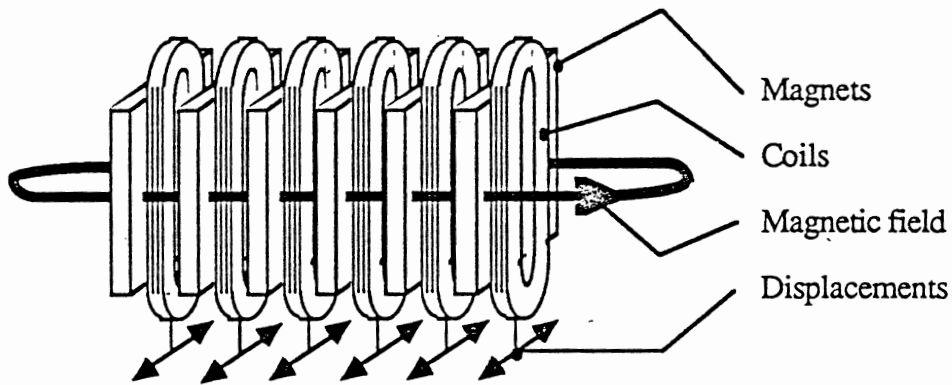


Figure 1. The "slice motor"

Figure 2. The sensor/motor module

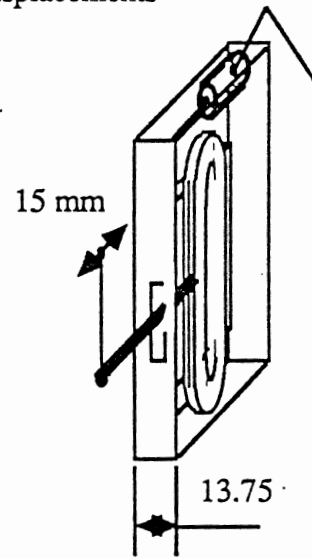


Figure 3.2.
Stick 1D

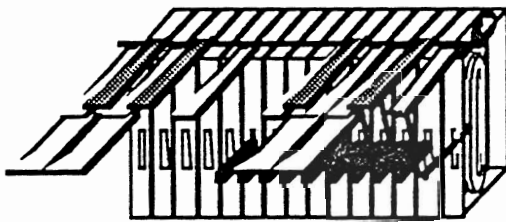


Figure 3.1. Keyboard

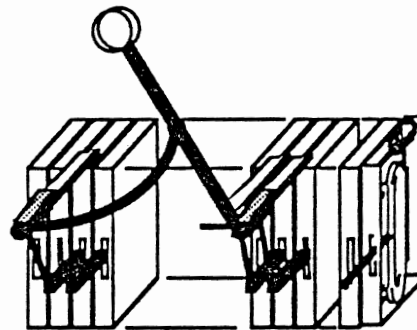
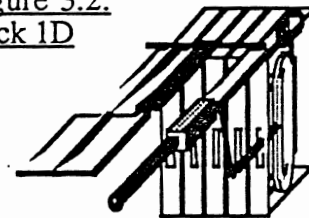


Figure 3.3. Stick 2D

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