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## Channel, afferent / efferent

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Literally, an afferent channel is a channel that carries material or impulses to a centre. While an efferent channel conducts outward from a part or organ.

In anatomy, afferent neurons carry nerve impulses from receptors or sense organs toward the central nervous system, and the efferent ones carry the impulses in the opposite direction. These two, impulse fluxes (afferent-efferent) create a "closed loop" system of sensation, decision, and reactions.

Within the field of automation and robotics, the efferent signal is the signal generated by the controller and transmitted to the robot. The afferent signal is the feedback signal from the sensors that allows closing the loop of the control.

This definition may be widened to the context of virtual reality / user interface and, even more generally, to the context of human computer interaction. In this field, the efferent channel is a communication channel that carries the information generated by the user (and measured by the artificial system) and transmits it to the artificial system (computerized environment). The afferent channel carries the information associated with the feedback (force, tactile stimulations etc.) of the artificial system as consequence of the user actions and transmits them to the user.

Such separation intrinsically exists when a mechanical system is represented – modelled, transformed - in input (efferent, resp. afferent) – output (afferent, resp. efferent) model. It exists since the physical equations [ $\rightarrow$  Algorithm] are computed (with or without computer) introducing for example the differentiation between “direct dynamics” in which the inputs of the computational sys-

tem are forces [ $\rightarrow$  Force] and the outputs are displacements (positions, etc.), and “inverse dynamics” in which there is the contrary. It exists when the mechanical system is transformed, by augmentation including sensors and actuators, to an electromechanical system. Consequently, Afferent and Efferent channels can be associated to different outputs/inputs of the Haptic Interface.

In telerobotics, it has been originally conceptually introduced in [Sheridan, 1992]. The creation of two different channels in the system model is a required step for making the interaction control-loop explicit. [Avizzano et al. 1999] proposed to sub-divided the data exchanged by means of the afferent and efferent channel into two levels:

- At the low level, called active information, signals are simply concerned with raw data contents having no relationship with the implicit content of the data itself (no degree of autonomous intelligence is requested to the control).
- At the high level, called reactive information, information on afferent and efferent channels are analyzed.

This distinction into two levels of each efferent – afferent channels allows designing a multilevel control structure which realizes the needed simplified control approach.

In their design of the physically-based modeller-simulator CORDIS-ANIMA [Cadoz et al, 1984], the authors theorised that when external mechanical universe is communicating with a computer by means of sensors and actuators (and their correlated analog-to-digital and digital-to-analog converters), the most general theoretical basis (necessary and sufficient conditions) to describe and implement this communication is through only two dual types of communication ports, called M and L. In each port, both types of physical data (intensive and extensive) are circulating, where the efferent channel of M conveys the intensive data and its afferent the extensive data (and vice – versa for the port L). All the physical communication between mechanical external world and

computer can be supported by a combination of these two duals ports, and only by them.

However, such distinction between afferent and efferent channels is not a natural concept: indeed, no separation between user mechanical actions and user mechanical responses exists in the mechanical nature. It introduces fundamental bias that is a conceptual causality between inputs and outputs (afferent and efferent channels) [Luciani 2004a], which does not exist in the mechanical world. More, when a mechanical system is transformed in an input-output (efferent – afferent) computational model, this bias has a very as the conceptual causality is transformed in a concrete causality that is here a temporal causality between input-output (efferent-afferent) channels that does not exist neither in the mechanical world. This added anti-physical causality creates the major theoretical and technical difficulties in simulating interactive systems including haptics, such as the critical role of the simulation frame rate, the limit in the simulation of the rigidity, etc [→ Stability].

Conversely, it leads to possible comparison of the human perceptual system, in which afferent and efferent channels exist de facto, to a computational system [Luciani 2004b], leading to confrontations between theoretical schools: mainly the enactive school and the computation theory of mind school [→ Computational paradigm].

## References

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