SYMPOSIUM PAPER

Prosthetics, Robotics and Remote Existence: Postevolutionary Strategies

Stelarc

ABSTRACT

The author probes the limitations of the body and discusses ways of extending the body's capabilities through technology, such as his Third Hand mechanism. Prosthetic devices, robotic structures and body-machine symbiosis are part of this unique performance artist's vision of our future.

OBSOLETE BODY

It is time to question whether a bipedal, breathing body with binocular vision and a 1,400-cc brain is an adequate biological form. It cannot cope with the quantity, complexity and quality of information it has accumulated [1]; it is intimidated by the precision, speed and power of technology, and it is biologically ill-equipped to cope with its new extraterrestrial environment. The body is neither a very efficient nor a very durable structure. It malfunctions often and fatigues quickly; its performance is determined by its age. It is susceptible to disease and is doomed to a certain and early death. Its survival parameters are very slim—it can survive only weeks without food, days without water and minutes without oxygen. The body's LACK OF MODULAR DESIGN and its overreactive immunological system make it difficult to replace malfunctioning organs. It might be the height of technological folly to consider the body obsolete in form and function, yet it might be the highest of human realizations. For it is only when the body becomes aware of its present predicament that it can map its postevolutionary strategies. It is no longer a matter of perpetuating the human species by REPRODUCTION, but of enhancing the individual by REDESIGNING. What is significant is no longer male-female intercourse but human-machine interface. THE BODY IS OBSOLETE. We are at the end of philosophy and human physiology [2]. Human thought recedes into the human past.

REDESIGNING THE BODY/REDEFINING WHAT IS HUMAN

It is no longer meaningful to see the body as a site for the psyche or the social but rather as a structure to be monitored and modified. The body not as a subject but as an object—NOT AS AN OBJECT OF DESIRE BUT AS AN OBJECT FOR DESIGNING. The psychosocial period was characterized by the body circling itself, orbiting itself, illuminating and inspecting itself by physical prodding and metaphysical contemplation. But having confronted its image of obsolescence, the body is traumatized to split from the realm of subjectivity and consider the necessity of reexamining and possibly redesigning its very structure [3]. ALTERING THE ARCHITECTURE OF THE BODY RESULTS IN ADJUSTING AND EXTENDING ITS AWARENESS OF THE WORLD. As an object, the body can be amplified and accelerated, attaining planetary escape velocity. It becomes a postevolutionary projectile, departing and diversifying in form and function.

THE INVASION OF TECHNOLOGY

Miniaturized and biocompatible, technology lands on the body. Although unheralded, it is one of the most important events in human history—focussing physical change on each individual. Technology is not only attached but is also implanted. ONCE A CONTAINER [4], TECHNOLOGY NOW BECOMES A COMPONENT [5] OF THE BODY. As an instrument, technology fragmented and depersonalized experience—as a component it has the potential to SPLIT THE SPECIES. It is no longer of any advantage to either remain 'human' or to evolve as a species. EVOLUTION ENDS WHEN TECHNOLOGY INVADES THE BODY. Once technology provides each person with the potential to progress individually in its development, the cohesiveness of the species is no longer important. What is intriguing is not the mind-body distinction but the body-species split. The body must burst from its biological, cultural and planetary containment. The significance of technology may be that it culminates in an alien awareness —one that is POSTHISTORIC, TRANSHUMAN and even EXTRATERRESTRIAL. (The first signs of an alien intelligence may well come from this planet.)

AMPLIFIED BODY, LASER EYES AND THIRD HAND

If the earlier events can be characterized as probing and piercing the body (the three films of the inside of the stomach, lungs and colon [6]/the 25 body suspensions) and determining the physical parameters and normal capabilities of the body, then the recent performances extend and enhance it visually and acoustically. Body processes amplified include brainwaves (EEG), muscles (EMG), heartbeat (ECG), pulse (PLETHYSMOGRAM) and blood-

Stelarc (artist), Advanced Computer Graphics Centre, Royal Melbourne Institute of Technology, Melbourne, Australia.

Based on a paper presented at the Second International Symposium on Electronic Art (SISEA), Gröningen, The Netherlands, 12–17 November 1990.

Pergamon Press plc. Printed in Great Britain.
0024-094X/91 $3.00+0.00

AMPLIFIED BODY

1. EEG (Brainwaves)
2. Position Sensor (Tilting Head)
3. Nasal Thermistor
4. ECG (Heartbeat)
5. EMG (Flexor Muscle)
6. Contact Microphone (Hand Motors)
7. Plethysmogram (Finger Pulse)
8. Kineto-Angle Transducer (Bending Leg)
9. Position Sensor (Bending Leg)
10. EMG (Vastus Medialis Muscle)
11. Ultrasound Transducer (Radial Artery Bloodflow)
12. Position Sensor (Lifting Arm)
13. Muscle Stimulation (Flexor Muscles)
14. Muscle Stimulation (Biceps B. Muscles)

THIRD HAND

A. Grasp/Pinch (Close)
B. Release (Open)
C. Wrist Rotation (C.W.)
D. Wrist Rotation (C.C.W.)
E. Tactile Feedback

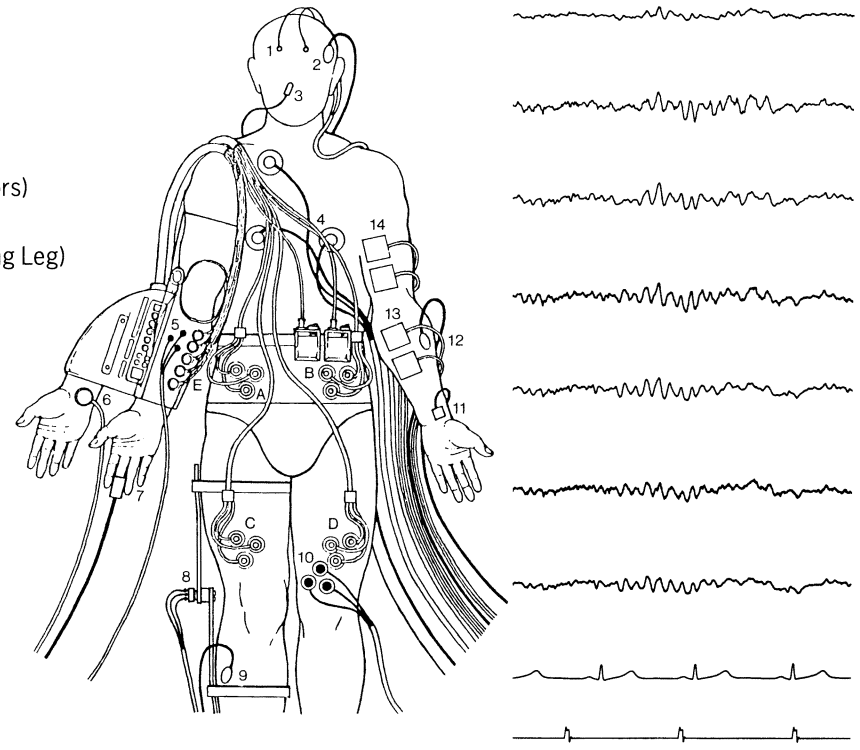

Fig. 1. Amplified Body/Third Hand diagram indicates the position of the electrodes and other sensors for amplifying body signals, muscle sites for stimulation (to produce involuntary jerking of the left arm) and the EMG control of the Third Hand. (© Stelarc)

flow (DOPPLER FLOW METER). Other transducers and sensors monitor limb motion and indicate body posture. The sound field is configured by buzzing, warbling, clicking, thumping, beeping and whooshing sounds—of triggered, random, repetitive and rhythmic signals. The artificial hand, attached to the right arm as an addition rather than a prosthetic replacement, is capable of independent motion, being activated by the EMG signals of the abdominal and leg muscles (Fig. 1). It has a pinch-release, grasp-release, 290° wrist rotation (clockwise and counterclockwise) and a tactile feedback system for a rudimentary 'sense of touch'. Whilst the body activates its extra manipulator, the real left arm is remote controlled—jerked involuntarily into action by two muscle stimulators. Electrodes positioned on the flexor muscles and biceps curl the finger inwards, bend the wrist and thrust the arm upwards. The triggering of the arm motions pace the performance and the stimulator signals are used as sound sources as are the motor sounds of the Third Hand mechanism (Figs 2–3). The body performs in a structured and interactive lighting installation that flickers and flares responding and reacting to the electrical discharges of the body—sometimes synchronizing, sometimes counterpointing (Figs 4–5 and Color Plate B No. 3). Light is not treated as an external illumination of the body but as a manifestation of the body rhythms. The performance is a choreography of controlled, constrained and involuntary motions—of internal rhythms and external gestures. It is an interplay between physiological control and electronic modulation. Of human functions and machine enhancement.

The Hollow Body

Off the Earth, the body's complexity, softness and wetness would be difficult to sustain. The strategy should be to HOLLOW, HARDEN and DEHYDRATE the body to make it more durable and less vulnerable. The present organ-ization of the body is unnecessary. The solution to modifying the body is not to be found in its internal structure but lies simply on its surface. THE SOLUTION IS NO MORE THAN SKIN DEEP. The significant event in our evolutionary history was a change in the mode of locomotion. Future development will occur with a change of skin [7]. If we could engineer a SYNTHETIC SKIN that could absorb oxygen directly through its pores and could efficiently convert light into chemical nutrients, we could radically redesign the body, eliminating many of its redundant systems and malfunctioning organs—minimizing toxin build-up in its chemistry. THE HOLLOW BODY WOULD BE A BETTER HOST FOR TECHNOLOGICAL COMPONENTS.

Pan-Planetary Physiology

Extraterrestrial environments amplify the body's obsolescence, intensifying pressures for its reengineering [8]. There is a necessity to design a more self-contained, energy-efficient body, with extended sensory antennae and augmented cerebral capacity. Unplugged from this planet—from its complex, interacting energy chain and protective biosphere—the body is biologically ill-equipped, not only in terms of its sheer survival but also in its inability to adequately perceive and perform in the immensity of outer space. Rather than develop specialist bodies for specific sites, we should consider a pan-planetary

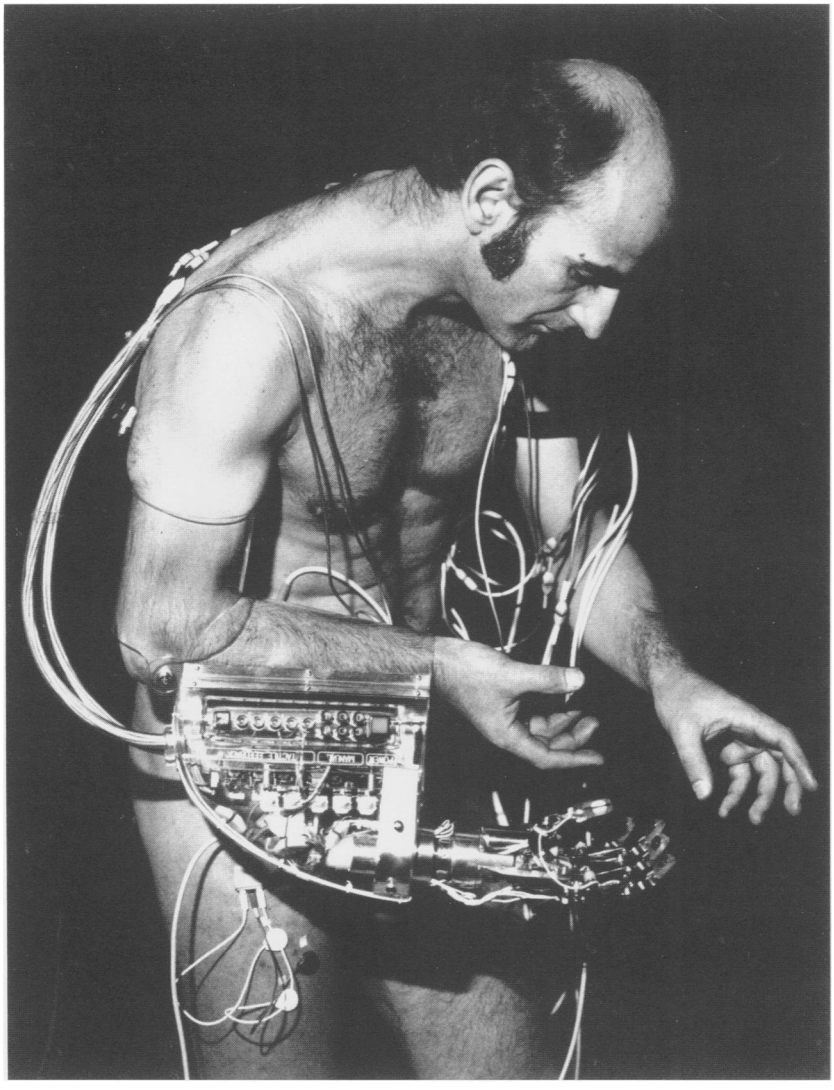

Fig. 2. Third Hand, Yokohama, Japan, 1976–1981. The artificial hand is attached to the artist's body not as a prosthetic replacement but as an additional hand. Materials used include duralamin, aluminum, stainless steel, molded acrylic and cast resin. Its vinyl cosmetic cover (cast from the artist's right hand) is not merely for appearance but protects the sensors and provides friction for gripping. Its functions include pinch-release, grasp-release, 290° wrist rotation (clockwise and counterclockwise) and a tactile feedback system for a 'sense of touch'. It was made to the dimensions of the artist's right hand. It is an EMG-controlled device, activated by abdominal and leg muscles to allow independent motion of the three hands. The design is based on the prototype developed by Ichiro Kato of Waseda University in Japan [10]. (Photo: Pamela Fernuik. © Stelarc.)

physiology that is durable, flexible and capable of functioning in varying atmospheric conditions, gravitational pressures and electromagnetic fields.

No Birth/No Death—The Hum of the Hybrid

Technology transforms the nature of human existence, equalizing the physical potential of bodies and standardizing human sexuality. With fertilization now occurring outside the womb and the possibility of nurturing the fetus in an artificial support system THERE WILL TECHNICALLY BE NO BIRTH. And if the body can be redesigned in a modular fashion to facilitate the replacement of malfunctioning parts, then TECHNICALLY THERE WOULD BE NO REASON FOR DEATH—given the accessibility of replacements. Death does not authenticate existence. It is an outmoded evolutionary strategy. The body need no longer be repaired but simply have parts replaced. Extending life no longer means 'existing' but rather being 'operational'. Bodies need not age or deteriorate; they would not run down or even fatigue; they would stall then start —possessing both the potential for renewal and reactivation. In the extended space-time of extraterrestrial environments, THE BODY MUST BECOME IMMORTAL TO ADAPT [9]. Utopian dreams become postevolutionary imperatives. THIS IS NO MERE FAUSTIAN OPTION NOR SHOULD THERE BE ANY FRANKENSTEINIAN FEAR IN TAMPERING WITH THE BODY.

The Anesthetized Body

The importance of technology is not simply in the pure power it generates but in the realm of abstraction it produces through its operational speed and its development of extended sense systems. Technology passifies the body. Because technology so successfully mediates between the body and the world, it disconnects the body from many of its functions. DISTRAUGHT AND DISCONNECTED, THE BODY CAN ONLY RESORT TO INTERFACE AND SYMBIOSIS. The body may not yet surrender its autonomy but certainly its mobility. The body plugged into a machine network needs to be passified. In fact, to function in the future and to truly achieve a hybrid symbiosis the body will need to be increasingly anesthetized.

Hybrid Human-Machine Systems

The problem with space travel is no longer with the precision and reliability of technology but with the vulnerability and durability of the human body. In fact, it is now time to REDESIGN HUMANS, TO MAKE THEM MORE COMPATIBLE TO THEIR MACHINES. It is not merely a matter of 'mechanizing' the body. It becomes apparent in the zero-G, frictionless and

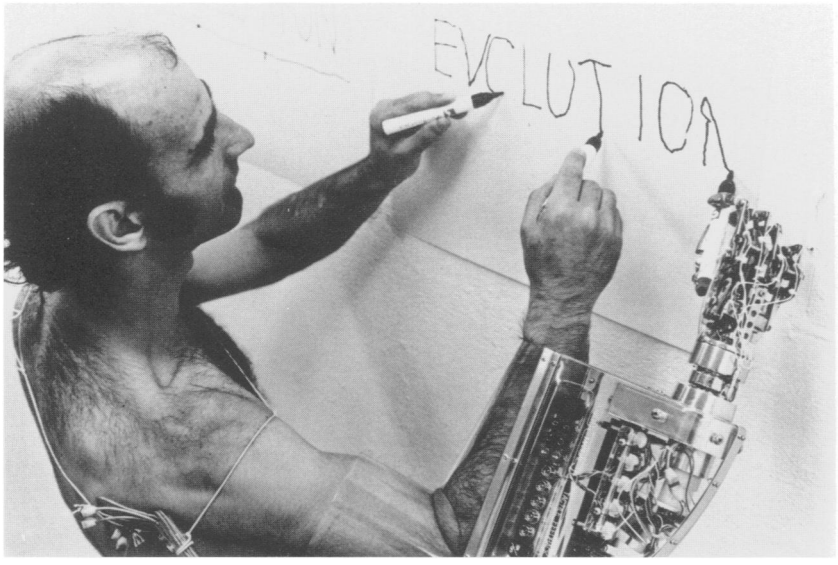

Fig. 3. *Handswriting*, **Maki Gallery, Tokyo, Japan, 22 May 1982. The performance entailed writing one word simultaneously with three hands. Because of the spacing of the hands, every third letter was written before the arms moved rightwards to write the next three. That is, the word was produced by the groupings E-L-I, V-U-O and O-T-N, respectively. The challenge for the artist was to remember what letter was being written by each hand at any given time and to keep his two eyes on what his three hands were doing. (Photo: Akiro Okada. © Stelarc.)**

oxygen-free environment of outer space that technology is even more durable and functions more efficiently than on Earth. It is the human component that has to be sustained and also protected from small changes of pressure, temperature and radiation. The issue is HOW TO MAINTAIN HUMAN PERFORMANCE OVER EXTENDED PERIODS OF TIME. Symbiotic systems seem the best strategy. Implanted components can energize and amplify developments; exoskeletons can power the body; robotic structures can become hosts for a body insert. And with micro-miniaturized robots we will now be able to colonize the surface and internal tracts to augment the bacterial populations—to probe, monitor and protect the body.

Towards High-Fidelity Illusion

With teleoperation systems, it is possible to project human presence and perform physical actions in remote and extraterrestrial locations. A single operator could direct a colony of robots in different locations simultaneously or scattered human experts might collectively control a particular surrogate robot. Teleoperation systems would have to be more than hand-eye mechanisms. They would have to create kinesthetic feel, providing the sensation of orientation, motion and body tension. Robots would have to be semi-autonomous, capable of 'intelligent disobedience'. With teleautomation, forward simulation—with time and position clutches—assists in overcoming the problem of real-time delays, allowing prediction to improve performance. The experience of Telepresence becomes the high-fidelity illusion of Tele-Existence. ELECTRONIC SPACE BECOMES A MEDIUM OF ACTION RATHER THAN INFORMATION. It meshes the body with its machines in ever-increasing complexity and interactiveness. The body's form is enhanced and its functions are extended. ITS PERFORMANCE PARAMETERS ARE LIMITED NEITHER BY ITS MERE PHYSIOLOGY NOR THE LOCAL SPACE IT OCCUPIES. Electronic space restructures the body's architecture and multiplies its operational possibilities.

References and Notes

1. The most significant planetary pressure is no longer the gravitational pull but rather the information thrust. Gravity has molded the evolved body in shape and structure and contained it on the planet. Information propels the body beyond itself and its biosphere. Information fashions the form and function of the postevolutionary body.

2. Human philosophy is overwhelmed by technological performance. The future becomes meaningful no longer through human imagination but by machine simulation. Humans become mere manipulators of machine images.

3. The desire to redesign the body is not to result in Yogic conditioning for spiritual pursuits, nor is it an obsession with Body Building for superhuman forms and feats. It is not about perfecting this body, for this body is obsolete. Shedding our present skin, discarding our evolutionary body as excess baggage and simplifying our internal structure whilst simultaneously modularizing and better integrating body systems are strategies that are necessary for a pan-planetary physiology.

4. The first phase of technological development was an explosive proliferation of discrete tools and instruments into the human landscape. As technology meshes into a network of systems, it surrounds and contains the body and even regulates its rhythms. The horizon becomes a technological event horizon that entraps and redefines the human condition. With increasing miniaturization and complexity, technology becomes biocompatible in both scale and structure. Technology im-

Fig. 4. *Automatic Arm, Laser Eyes and Third Hand*, **International Festival, Melbourne, Australia, 13–29 September 1990. The artist's body was plugged into a transparent performance pod with an interactive lighting installation, actuated and modulated by the amplified body signals. With the left arm jerked up and down by muscle stimulators, there was an interplay between controlled, constrained and involuntary motion. Laser beams alternated from eye to eye in emanation, piercing and probing the space. Although contained within the hexagonal structure, the on-and-off flaring of the lighting expanded and contracted the body's space with the multiple reflections. The performance image oscillated between the geometry of the pod structure and the form of the body. (Sound coordination: Rainer Linz, lighting installation: Nathan Thompson. Photo: Tony Figallo. © Stelarc.)**

plodes back to the body where it can be attached and implanted.

5. And how does the body react to this intrusion of technology? Well, the human species has no immunity to technology. Over millions of years we have developed an immunological response to harmful bacteria and viruses, but technology has been too recent a phenomenon in our evolutionary history. If the bits of implanted technology are small, soft or packaged in inert, nontoxic and sterile material, the body treats them with indifference. In other words, the body welcomes technology.

6. The three 16-mm color films of the inside of the body were done with the assistance of M. Kitagawa at the Yaesu Cancer Research Center in Tokyo and at Hamamatsu Hospital. To record 15 min for each probe, it was necessary to keep the fibrescope inserted for 2–3 hr in the body. The experience was most difficult—nauseating and painful, using cumbersome medical equipment. For the stomach and colon probes, it was necessary to inflate the body with air and flood the tracts with light. A traumatic incident in filming with the first body probe was the discovery of a polyp inside the stomach. What began as an artistic experiment quickly deteriorated into a medical melodrama. The doctor had to perform a biopsy then and there. With the insertion into the large intestine it was possible for me to handle the camera, peering and probing 90 cm into my body. To film the inside of the bronchi of the lungs, it was necessary to first insert a hollow tube through the mouth into the trachea to be able to guide the fibrescope into the body. The total internal space filmed, approximately 2.4 m, exceeds my height.

7. On Earth the body's metabolism ebbs and flows with night and day, its brainwaves rhyme with the electromagnetic pulse, and its psyche changes with the seasonal shifts. To adequately exist in outer space, it will be necessary to radically vary our metabolic rate—homeostasis now becomes a problem, and circadian rhythms are too regular and rapid.

8. Ergonomics, or human-factors engineering, has thus far been concerned with designing technology that takes into account human characteristics such as physiological parameters, sensory capabilities and psychological limitations. Factors such as body proportion and posture, reaction time and attention span, the brain's decision-making processes and strain and fatigue considerations have to be taken into account. But it is no longer a matter of merely making machines compatible for humans. It is not a matter of designing technology to augment the deficiencies of the body. It is time to fine-tune humans to match their machines.

9. The notion of immortality is used in neither a spiritual nor utopian sense. Clearly, the body's life span needs to be exponentially extended for it to function adequately in the expanded space and extended time of the extraterrestrial environment.

10. The Third Hand was made with the assistance of Imasen Denki.

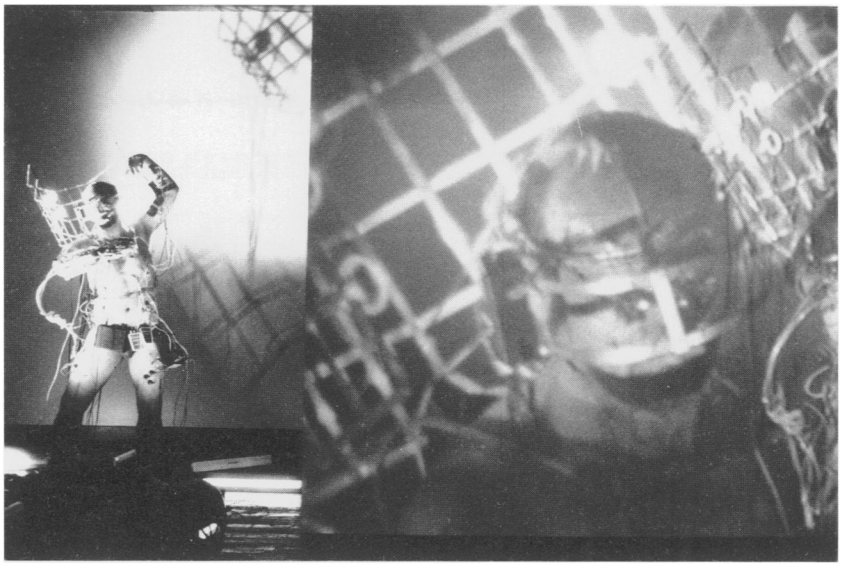

Fig. 5. ***Interface/Interplay: Extended Body, Video Shadow*****, Experimenta, The Malthouse, Melbourne, Australia, 2 December 1990. The artist's body constructed and choreographed its video shadow with four cameras arrayed around and above it, triggered by tilting the head, lifting the Third Hand and the involuntary, automated movement of the left hand. One of the images was in strobe motion, disrupting the flow between the body and its video shadow. The body monitored the screen, switching and superimposing images in synchrony with its amplified rhythms and gestures. (Sound coordination: Rainer Linz, lighting installation: Nathan Thompson, interactive video system: Simon Wilmot. Photo: Tony Figallo. © Stelarc.)**

Bibliography

Baudrillard, J., *Simulations* (New York: Semiotext[e], 1983).

Baudrillard, J., *Selected Writings*, M. Poster, ed. (Stanford, CA: Stanford Univ. Press, 1988).

Boden, M. A., *Artificial Intelligence in Psychology: Interdisciplinary Essays* (Cambridge, MA: MIT Press, 1989).

Conway, L., Volz, R. A. and Walker, M. W., "Tele-autonomous Systems: Projecting and Coordinating Intelligence Action at a Distance", *IEEE Transactions on Robotics and Automation* **6**, No. 2 (1990).

Crosson, J. and Sayre, K. M., ed., *Philosophy and Cybernetics* (Notre Dame, IN: Univ. of Notre Dame Press, 1967).

Debord, G., *Society of the Spectacle* (Detroit, MI: Black and Red, 1983).

De Rossi, D., Nannini, A. and Domenici, C., "Artificial Sensing Skin Mimicking Mechanoelectrical Conversion Properties of Human Dermis", *IEEE Transactions on Biomedical Engineering* **35**, No. 2 (1988).

Fishlock, D., *Man Modified* (London: Granada, Paladin, 1971).

Fodor, J. A., *The Modularity of the Mind: An Essay on Faculty Psychology* (Cambridge, MA: MIT Press, 1983).

Graubard, S. R., ed., *The Artificial Intelligence Debate: False Starts, Real Foundations* (Cambridge, MA: MIT Press, 1989).

Heidegger, M., *The Question Concerning Technology and Other Essays*, W. Lovitt, trans. (New York: Harper & Row, 1977).

Hirose, S. and Umetami, Y., *The Basic Motion Regulation System for a Quadruped Walking Vehicle* (New York: American Society of Mechanical Engineers, 1980).

Hookway, C., ed., *Minds, Machines and Evolution* (Cambridge, England: Cambridge Univ. Press, 1986).

Ihde, D., *Existential Technics* (Albany, NY: State Univ. of New York Press, 1983).

Iwata, H., "Artificial Reality with Force Feedback: Development of Desktop Virtual Space with Compact Master Manipulator", *Computer Graphics* **224**, No. 4 (1990).

Jacob, F., *The Possible and the Actual* (New York: Pantheon, 1982).

Kamper, D. and Wulf, C., eds., *Looking Back at the End of the World* (New York: Semiotext[e], 1990).

Kazerooni, H., "Human-Robot Interaction via the Transfer of Power and Information Signals", *IEEE Transactions on Systems, Man and Cybernetics* **20**, No. 2 (1990).

Leder, D., *The Absent Body* (Chicago: Univ. of Chicago Press, 1990).

Lenihan, J., *Human Engineering: The Body Re-Examined* (New York: George Braziller, 1976).

Mitcham, C. and Mackey, R., eds., *Philosophy and Technology: Readings in the Philosophical Problems of Technology* (New York: Free Press, 1983).

Mumford, L., *Technics and Civilization* (New York: Harcourt, Brace & World, 1963).

Nakano, Y., Fujie, M. and Hosada, Y., "Hitachi's Robot Hand", *Robotics Age: Journal of Intelligent Machines* (Peterborough: Robotics Age).

Russell, R. A., "Design of a Parallel Actuated Dexterous Robot Gripper", in *Proceedings of the Third National Conference on Robotics*, 3–6 June 1990 (Melbourne: Australian Robot Association, 1990).

Searle, J., *Minds, Brains and Science*, 1984 Reith Lectures (London: British Broadcasting Corporation, 1984).

Simon, H. A., *The Sciences of the Artificial*, 2nd Ed. (Cambridge, MA: MIT Press, 1982).

Tachi, S., Arai, H. and Maeda, T., "Robotic Tele-Existence", in *Proceedings of the NASA Conference on Space Telerobotics*, Publication No. 89-7 (Pasadena, CA: Jet Propulsion Laboratories, 1989).

Tax, S., ed., *The Evolution of Man: Man, Culture, and Society* (Chicago: Univ. of Chicago Press, 1977).

Trigg, R., *The Shaping of Man: Philosophical Aspects of Sociobiology* (Oxford: Basil Blackwell, 1982).

Uttal, W. A., "Teleoperators", *Scientific American* **261**, No. 6 (1989).

Virilio, P., *Speed and Politics* (New York: Semiotext[e], 1986).