The future synergy of computer modelling and smart technologies in sport

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Abstract

Computational modelling in biomechanics and specifically in sport performance has been constantly evolving and developing. However, frequently emphasis has been put sometimes complex modelling and sometimes extremely simplistic techniques that yield results impossible to validate and have little or no practical impact. An example of the former is modelling of cartilage as a multiphase continua and the latter is very evident in a number of publications devoted. However, the problems are normally attributed to modelling but they also lie in the provision of input and validation from both experiments and competition.

The above point is illustrated by a practical example of a project on the scale of the propulsive force in swimming. The project relied on combination of computational modelling, experimental data collection including the construction of a robotic arm and data from competition level training sessions. As a result it is now known the level of forces involved in front crawl swimming, and will soon be possible to optimise the stroke trajectory in terms of maximum thrust generated. However, is this sufficient? The human being is not designed to swim so to talk about optimal stroke is ill-founded. Such “optimum” is dependent on physiological constrains and hence more multidisciplinary approach is needed.

The problem with the analytical approach presented above is that it enhances the scientific knowledge and understanding but does not show the way ahead in terms of how practically this could be achieved. Currently strong emphasis is given to the rapid feedback provision for the athletes. But this has a lot of limitations as it is hardly rapid and depends on the individual interpretation of the data collected by coaches and technical staff.

A parallel development and it up to now a separate one are the so called smart technologies, the best known examples of which are smart materials such as piezoelectric ones and memory shape alloys. Up to know mostly smart materials have been developed and used. They have the propensity to react to change in the environmental parameters. However, their response is limited to a small number of parameters. However, the more recent trend is towards “intelligent” technologies and materials that could offer a variety of responses and differentiate the factors contextually. The author believes that computers will be playing a more prominent role in this development. This is illustrated with some ongoing projects devoted to drug testing and individualised comfort. Possibilities for the use of these novel technologies in sport are discussed. The author strongly believes that such approaches should end the deeply flawed statistical approaches in very near future.

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Introduction

Computers have been rapidly evolving over the lost decade and entering in all different areas of lives. However, some of the new developments have been taking place in isolation not allowing the full use of the great advantages of theoretical, computer and technological development to be fully utilised.

Sport is an area inherently inter- and multi-disciplinary that allows combined of application of new theoretical develop, novel computational techniques and advanced new technologies.

The aim of the current work is to outline the possibilities of the utilisation of novel computational techniques in seemingly unrelated area such as aerospace engineering, physiology, biomechanics and medicines in a coherent approach. The argument is built on three case study as it is proposed that the integrated system will combine ubiquitous computing, smart materials and artificial intelligence approaches to allow individualised training and relaxation schedule for the athletes.

Case 1: Modelling in Swimming

Swimming research has been for years using an over-simplistic approach of calculating the propulsive force based on quasi-static assumptions for drag and lift.

$$L = \frac{1}{2}\rho u^2 C_l S$$

$$D = \frac{1}{2}\rho u^2 C_d S$$

A number of both theoretical and experimental studies have been published but at the end neither the scale of the propulsive nor the relative contribution of the lift and drag were established.

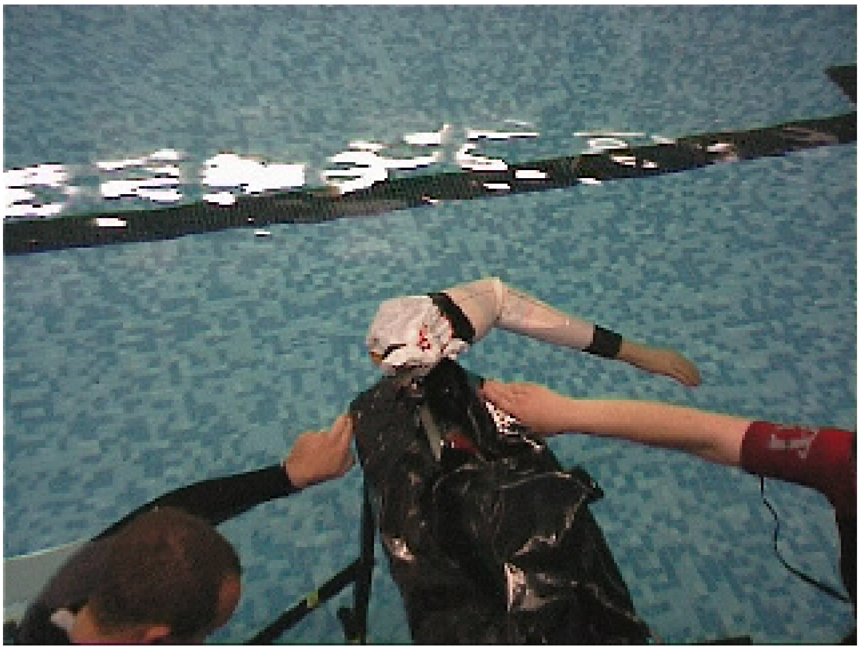


Fig.1. Running the swimming arm in a swimming pool

Due to the above a long term project was set up with two folds aim:

i) to establish the sale of the propulsive force and

ii) ii) to devise a model that allows to assess the scale of the swimming forces.

The work started initially with designing a robotic arm capable of simulating the speed profiles of elite swimmer's arm (see Fig.1). The arm was computer controlled and data for the forces was automatically collected, hence the two computers in Fig.2.

Fig.2. Experimental configuration

After obtaining the data (see Lauder and Dabnichki, 2005), it was established that the up to date estimates are not very accurate and that a more sophisticated model of hydrodynamic forces was needed. Hence a new computational model based on integral equations and more specifically the Boundary Element method was developed. However, this model needed inputs that were not readily available and this lead to the use of windtunnel experiments for provision of accurate input data.

Fig.3. Windtunnel experiments

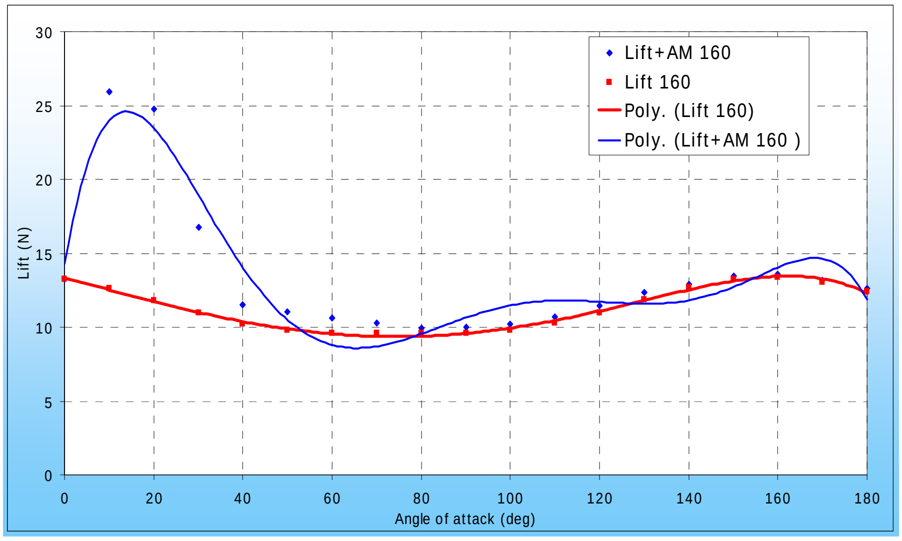


Fig.4a. Arm lift at 160^{o} elbow angle.

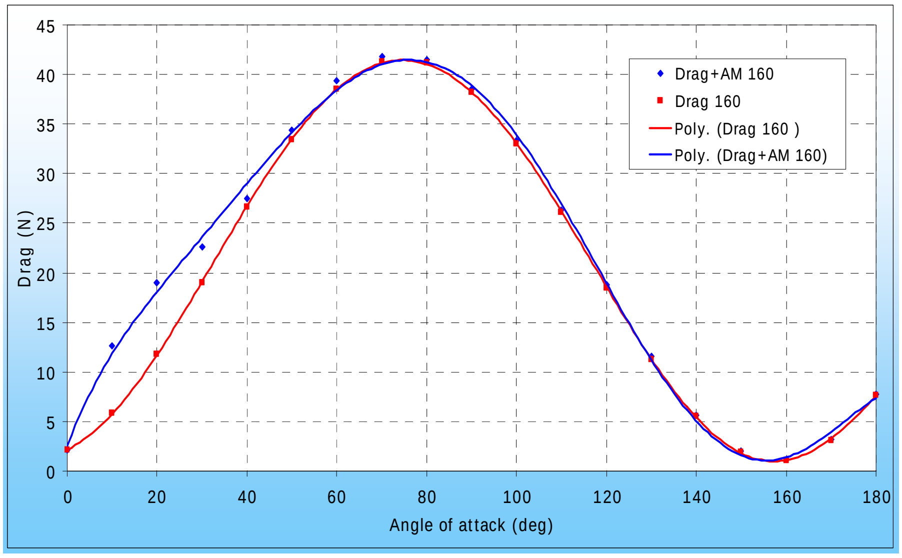


Fig.4b. Arm drag at 160^{o} elbow angle.

Results for the lift and drag of the human arm in water. The study established the actual values and showed the deficiencies in pre-existing studies.

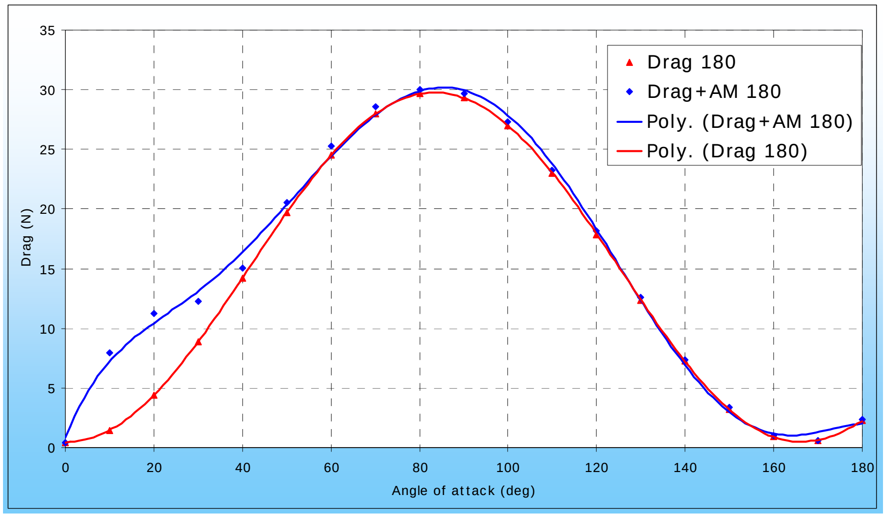


Fig.5a. Arm lift at 180^{o} elbow angle (arm fully abducted).

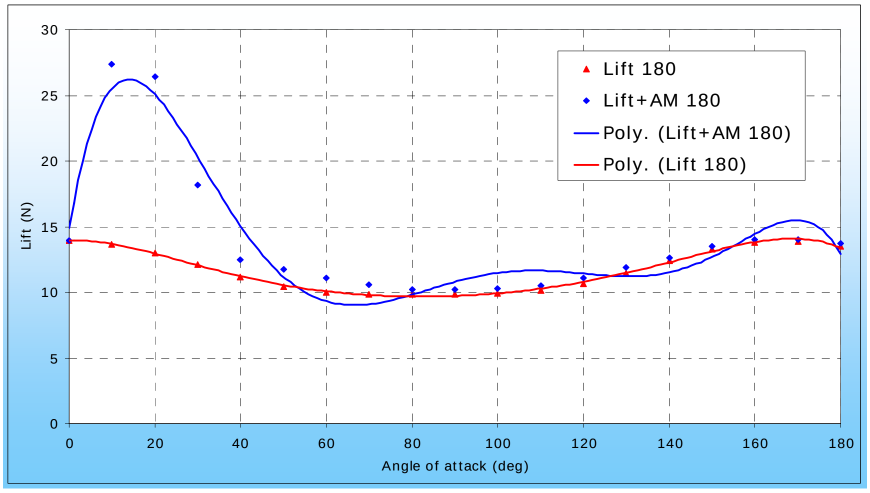


Fig.5b. Arm drag at 180^{o} elbow angle (arm fully abducted).

The combined experimental and computational method allowed to gain further insight into propulsive force generation. However, the results could neither be compared to existing ones as there was a paucity of such data and direct measurement is virtually impossible. Hence the robotic arm data were used for validation. These comparisons are presented in figs 6 a,b,c below.

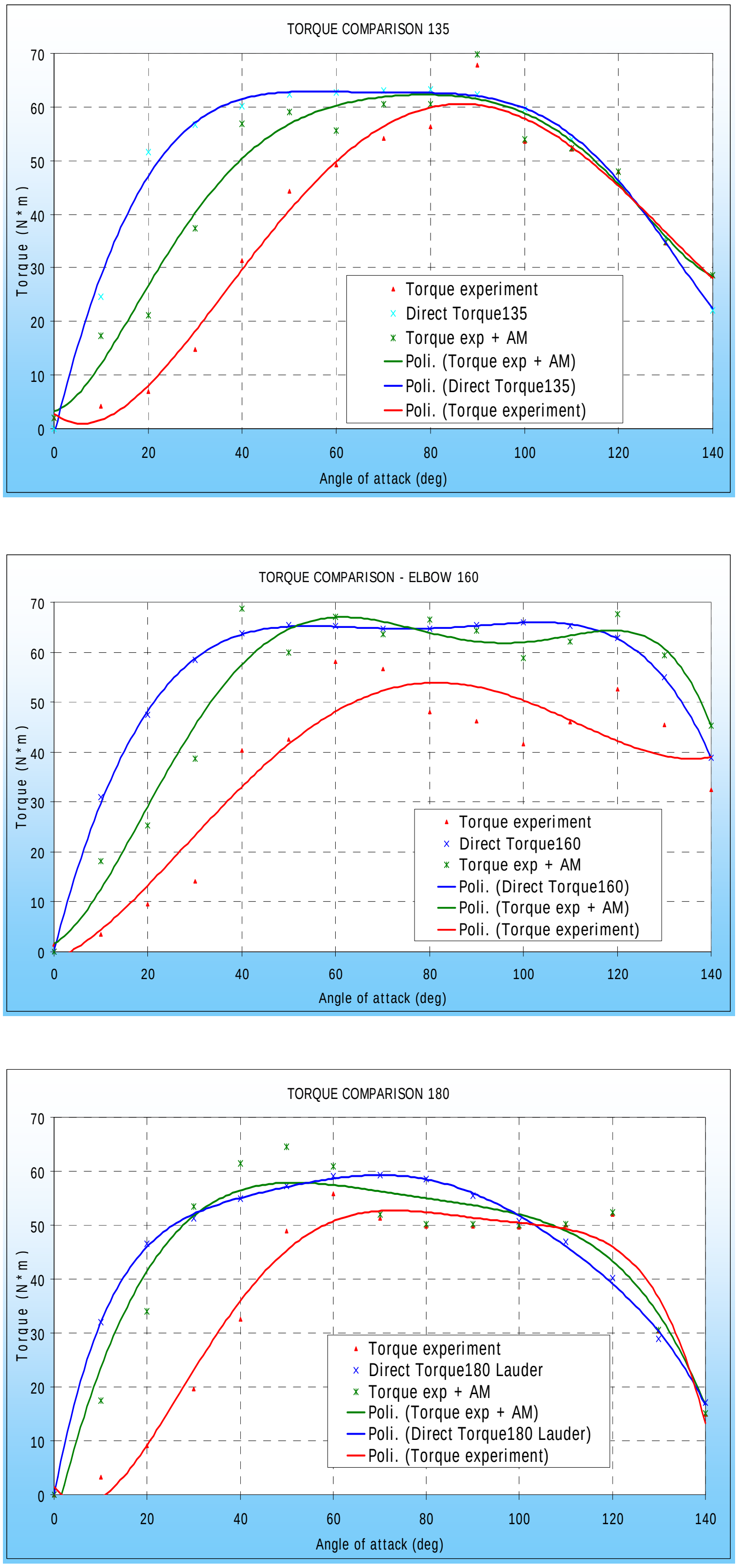


Fig6a,b,c. Torque comparison at variety of elbow flexion angles.

The presented comparison showed the robustness of the proposed approach and allowed to move to the next stage – modelling of real swimming stroke. This study has just been completed and the results show some very interesting findings. First it seems that the importance of lift has been overstated and overexposed by previous and more recent research including some computational studies utilising CFD packages. Second it seems that the famous S-shape stroke is not as much as to increase the lift but to actually roll the body to allow increase in the stroke range.
The study lead us to question that optimisation of the stroke is possible without considering the human physiology.
The answer is most certainly no, but there is a major problem with physiological data – it is scarce, frequently collected without proper universal protocols and very frequently non-recognisable due to heavy statistical manipulations.

Hence and idea for developing a monitoring system based on a development for the drug testing industry which is the issue discussed in case 2.

Case 2: Monitoring and Analysis of Patient Condition and Response to Treatment

An integrated system for patient monitoring in hospital environment has been developed. The system is a central depository that collects information from a variety of devices and creates records in a central depository. The purpose of the system is to completely replace annual inputs with an automated approach. The system consists of both software and interface hardware. The system is a further development of a system for monitoring of elite Olympic athletes with target application of monitoring of drug trials. The system development is a multiphase project that aims to deliver fully automated synchronised monitoring with appropriate alert options and is to be fully functional in the next year (stage 1&2 on the chart in Fig.7). The next phase will focus on stage 3 data analysis. While stage 4 is to focus on intelligent and targeted drug delivery for the individual user.

Opportunities for Sport

Two opportunities seem plausible:

i) Intelligent and remote drug testing and
ii) Design of optimal recovery and training routines if used in conjunction with wearable sensors

the importance of the proposed approach lies in the embedded use of periphery and automated analysis and response. The difference between the proposed approach and frequently discussed smart drug delivery approaches is that this is a multifunctional and contextual approach and not a trigger response to a change in a single parameter.
This approach is best illustrated in the next example where a system is developing learning skills and individualized approach to the user.

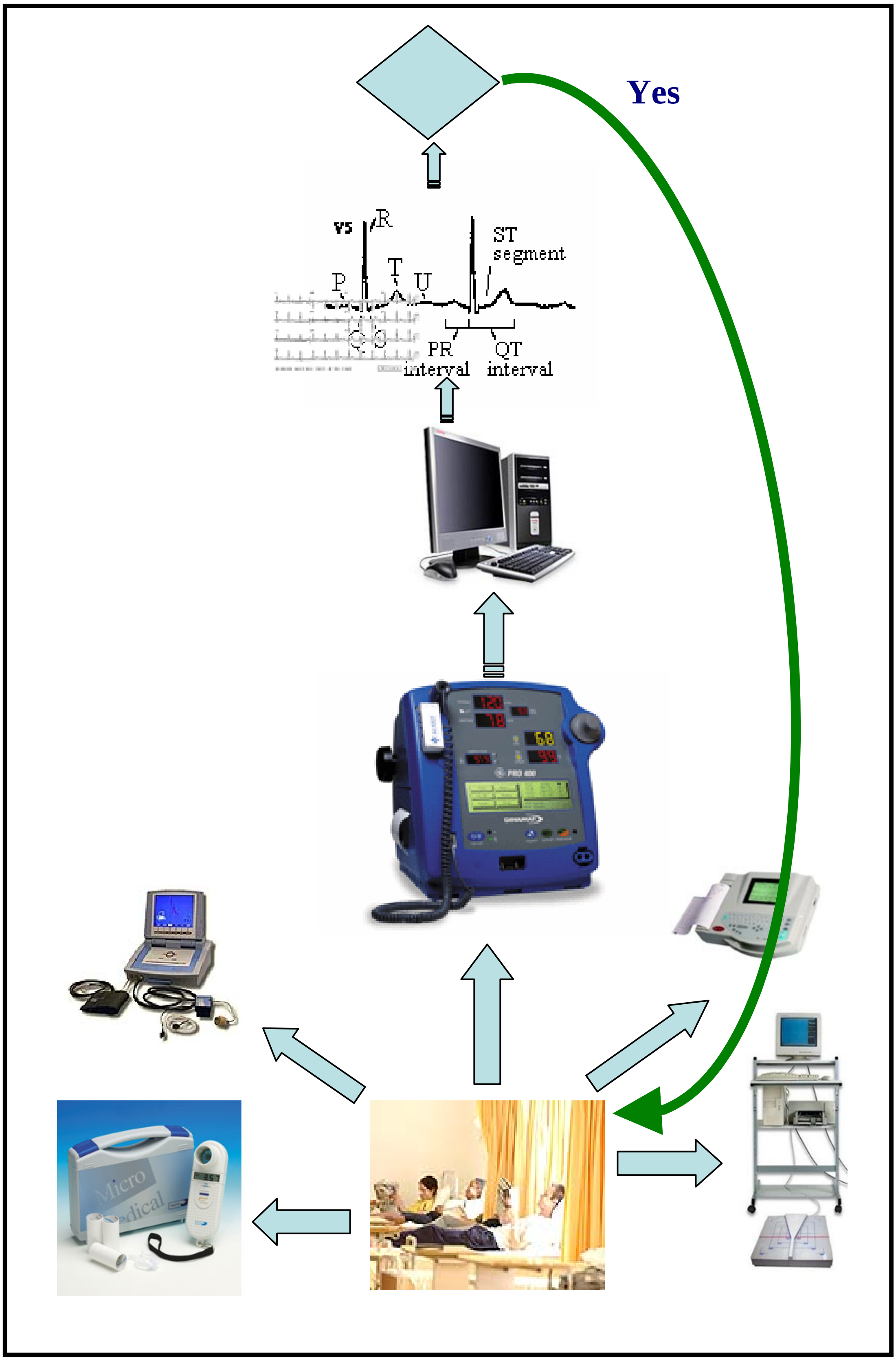
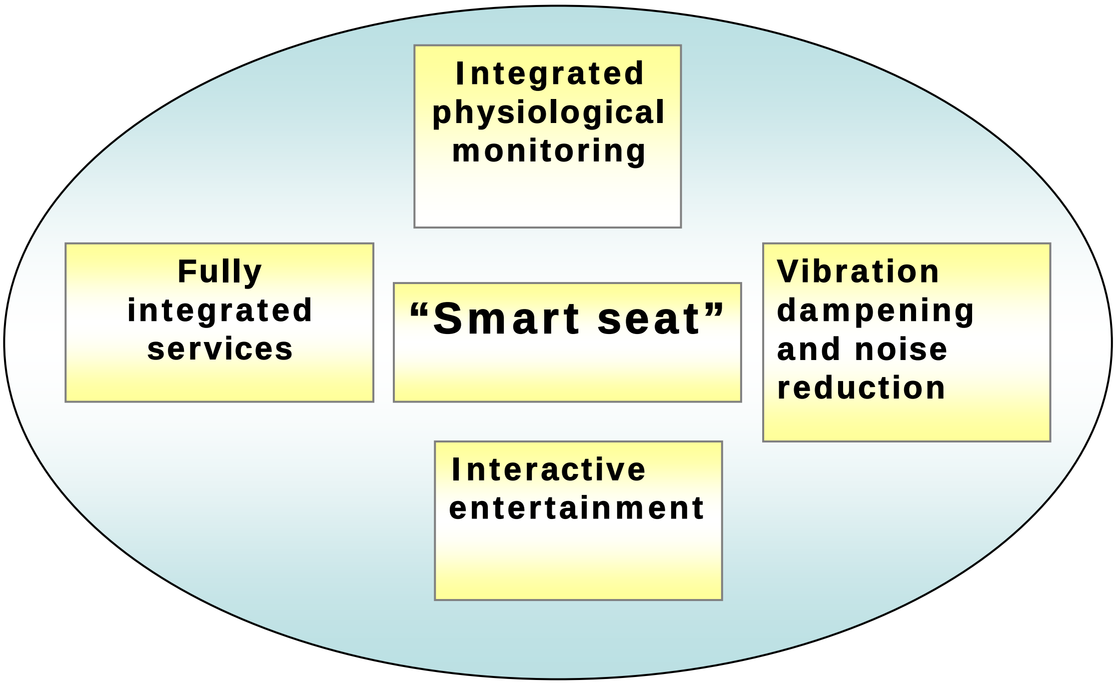


Fig.7. System design.

Fig.8. Controlled blood pressure measurement.

Case 3: Smart Seat for Aeroplanes

The proposed system is currently is currently being developed under the EC FP6 framework. It is in conjunction with a number of universities, research institutes and industries.



It is a system that intelligently assesses the individual needs of the passenger and responds by controlling the microclimate, global environmental factors such as unwanted vibrations, noise, etc. within the individual area and delivers optimal control of selected set of parameters without customer intervention. The heart of the system is a physiological monitoring system.

Opportunities for Sports Applications

The main pillar of the project is physiological monitoring system that utilises a number of advanced technologies including wearable sensors and is integrated within the existing on-board systems. This system could be easily adapted for monitoring of elderly, children or other risk groups with minimum interference to their lifestyle. Furthermore the system could provide alerts or automatic responses as it does on the plane.

Conclusions

- However, it is very likely that the new trends such as ubiquitous computing, pervasive computing etc. are the once that will be best suited for field applications.
- It will be possible to greatly reduce the number of support staff with limited knowledge and capabilities with intelligent systems complemented with high calibre specialists.
- Computers will become a lot more widely and intelligently used in sport, not just for archiving.

Reference

Gardano P and **Dabnichki, P** Application of Boundary Element Method to Modelling of Added mass and its effect on hydrodynamic forces, *CMES, (in press)*

Dabnichki, P and Avital, E (2006) Influence of the position of crewmembers on aerodynamics performance of two-man bobsleigh *J. Biomechanics* (*in press*)

Gardano P and **Dabnichki, P** (2006) On hydrodynamics drag and lift of human arm, *Journal of Biomechanics*. (*in press*)

Taylor MJD, Strike SC and **Dabnichki P** (2006) Strategies used for unconstrained direction change during walking. *Perceptual and Motor Skills,* **102**, 576-588.

Taylor MJD, Strike SC and **Dabnichki P** (2006) Turning bias and lateral dominance in able-bodied and amputee populations. *Laterality, (in press)*

MJD Taylor, **P Dabnichki,** and SC Strike (2005) A three-dimensional biomechanical comparison between turning strategies during walking. *Human Movement Science,* **24**(4), 558-573

Dabnichki, P and Zhivkov A (2005) Analytical Approach to cell geometry reconstruction *Computer, Materials and Continua*, 2(2), 97-104.

Lauder MA and **Dabnichki P** (2005) Estimating propulsive forces **-** sink or swim? , *Journal of Biomechanics,* **38**, 1984-1990.

Dabnichki P, Avital E and Motallebi F (2004) Advanced bobsleigh design: Part A Body protection, injury prevention and performance improvement, *Proc. of IMechE part L: Journal of Materials: Design and Applications,* **218**, 129-138. **invited peer reviewed publication**

Motallebi F, **Dabnichki P** and Luck D. (2004) Advanced bobsleigh design: Part B Aerodynamics, *Proc. of IMechE part L: Journal of Materials: Design and Applications* **218**, 139-144.

Lauder MA, **Dabnichki P** and Bartlett RM (2001) Improved accuracy and reliability of sweepback angle, pitch angle and hand velocity calculations in swimming, *Journal of Biomechanics*, **34**, 31-39.

Lauder MA, **Dabnichki P** and Bartlett RM (2000) Angular measurement accuracy of three-dimensional video analysis in air and underwater conditions at different movement frequencies. *Journal of Sports Sciences,* **18**(1)**,** 8-9.

Dabnichki P (2006) Mathematical and computational model of global cell mechanical responses" invited review in a world series 'Recent Research Developments in Biomechanics' 3(2006): 1-13 ISBN: 81-7895-195-9 **invited contribution**

Dabnichki, P. (2005) Integrity and Durability of Winter Sport Equipment, "ICCES'05: International Conference on Computational & Experimental Engineering and Sciences" (**keynote**)

Dabnichki P (2005) Smart Structure in Sport, 4th Int. Conference on Fracture and Damage Mechanics, in Advances in Fracture and Damage Mechanics, Mallorca, Spain 2005. **pp.** 359-364. **(invited)**

Dabnichki P (2005) Fast Mesh generator for Boundary Element Analysis of static and dynamic problems forces, Adv. Bound. Elem. VI, Proc. of the International conference on BEM, Montreal. EC Publ. pp. 261-266.

Gardano P, **Dabnichki P** and Aliabadi MH (2005) Application of Boundary Element Method to modelling of hydrodynamic forces, Adv. Bound. Elem. VI, Proc. of the International conference on BEM, Montreal. pp. 217-223.

Dabnichki P (2004) Improved aerodynamics and improved safety in bobsleigh design. AED 2004, Glasgow, C-305, ISBN 80-86059-41-3.

Sabelstrom E and **Dabnichki P** (2004) Establishing design parameters and efficiency of design through biomechanical tests. AED 2004, Glasgow, A-205, ISBN 80-86059-41-3.

Khurram K and **Dabnichki P** (2004) Calf muscle ergometer. AED 2004, Glasgow, A-206 ISBN 80-86059-41-3.

Dabnichki P (2003) Improved aerodynamics and improved safety in bobsleigh design. AED 2003, Prague, B-27, ISBN 80-86059-35-9.

Dabnichki P (1998) Biomechanical tests of sport equipment, *Journal of Sport Engineering*, **1**(2), 93-105.

Lauder MA and **Dabnichki P** (1998) A scaled down environment for assessing the static accuracy of three-dimensional space reconstruction using the direct linear transformation in air and underwater conditions. *Journal of Sports Sciences*, **16**(1), 11-12.

Dabnichki P and Taktak D (1998) Pressure variation under the ischial tuberosity during a push cycle, *Medical Engineering and Physics*, **20**(4), 242-256.

Aritan S, **Dabnichki P** and Sargeant AJ (1998) In vivo measurement of bulk muscle properties in humans *Journal of Physiology-London,* **506**, 10-11.

Aritan S, **Dabnichki P** and Bartlett R (1997) Program for generation of three-dimensional finite element mesh from magnetic resonance imaging scans of human limbs, *Medical Engineering and Physics,* **19**(6), 681-689.