Safety by a Sensor-Based Timely Perception: An Interdisciplinary Approach for Walking Robots

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Introduction

It is a difficult task for walking robots in unknown environments to maintain a safe system behaviour, in particular for walking robots with less than 6 legs on ground with different soil properties. To encounter the drawbacks [ID,KO] of mechanical approaches maintaining the problem of postural control, we propose a new biomechanical approach. The approach addresses difficult problems like break-through (fig.1) or sagging and supports walking by an intelligent way of control. Therefore interdisciplinary investigations in soil physics [HA], motion behaviour of vertebrates [SGS], and acoustics[SF] elucidate the area of interest. The following approach is based on these investigations and gives a better understanding of motion control. One step to control the interface between body and surface can be achieved by analysing characteristic data at specific events while acting on ground.

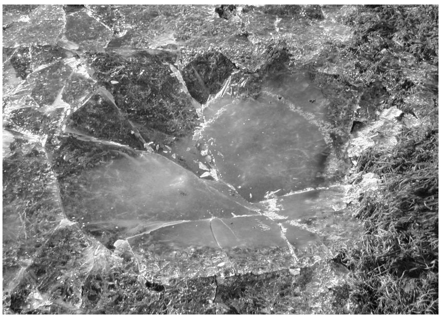

Fig. 1: Break-through, a problem of a walking robot

Approach of a timely perception

To improve control, the following aspects must be regarded in soil physics. Depending on material structure the appearance of crevasses, cracks, fissures, leakage, or deformations are attend by emitting acoustic waves if loading the surface.

1. During compression of ground by the robot-leg emission of acoustic waves is probable. After loading these emissions disappear. Otherwise a demolition of the soil structure might have occurred.

2. Sliding action on ground: It is very difficult to compute precise values of sliding friction depending on soil properties. But as mentioned above, acoustic waves caused by sliding on soil can be detected and help to act timely.

Postural behaviours are both reactive and predictive. For the control of a walking robot we have to reflect these insights including aspects of *acoustics.* In [SGS] the *audiogenic stepping (stepping initiated by acoustic signals)* is reported, where stimulation (startle-eliciting stimuli) of the cochlear nuclei (central nucleus of the sense of hearing in inner ear) can precociously elicit locomotion (Primary Defensive System). *To control this interface of body and surface means to control the actions and reactions.*

Some insights in the world of sound will help to understand and to develop an appropriate model for control of movements. What can we learn and adopt for the domain of robotics? To understand human delusion in perception it should help to get insight in the area of acoustics. E.g. the perception at the exact point in time of the contact of a foot with the surface or that one of a string with the guitar delivers a corresponding sound [SF].

The basic idea of our approach is to *systematically exploit also acoustical information for predicting the state of the terrain* in which the robot is manoeuvring, i.e. to evaluate and interpret noise patterns generated by the ground as a *response to movements of the robot leg*. This is currently under investigation, by means of an experimental platform:

LAURON-II [LAU] contains

- a sensor/actuator architecture to deliver efficient environmental information and computational architecture to manage the tasks generated by sensors and actuators.

This comprises the following issues:

- An efficient sensor-actuator concept and interfacing as investigated in vertebrates. Managing the computational power to handle the lot of tasks generated by sensors and actuators exploiting the environment by TAFT(Time Aware Fault Tolerant scheduling) [NE]. Furthermore the ability to start, stop and continue a task generated by sensors and actuators at any time.

Therefore, a new sensor model in a sandwich structure containing force sensor, acoustic component and in a next step a piezo component will enhance the perceptibility and the reactivity supported by efficient algorithms. The LAURON-II platform provides in a very interesting basis for applying different strategies of software partitioning and scheduling of resources. The following steps for future work can be envisioned: An application scenario will be defined, including the respective runtime tasks. The defined tasks will be implemented in the existing architecture, consisting of PC104 running RT-Linux, and the C167 without OS. The P/S protocol [RG] should be used as the communication model. In parallel, experiments with the new prototype of a robot leg will be made. Dynamic aspects related with the developed application will be investigated, in order to find out, whether dynamic scheduling, like the TAFT scheduling used for the higher levels of the control architecture, is required for the lower (micro controller) level as well. If required, different options for implementing a dynamic scheduler in the micro controller architecture will be evaluated (including using μ CLinux in the MC). A distributed scheduling strategy will be defined, in order to

fulfil the application requirements and utilize the available runtime infrastructure. Finally a demonstration scenario will be defined and implemented.
Sound initiated by foot load on a surface can be recorded for transformation analysis by a microphone close to foot and surface like a sandwich. The sound information will be transformed into a frequency spectrum and the sequence of frequencies will be used to analyse the appearance of typical surface/soil behaviour like break-through or sagging, clearly differentiated from waves generated by normal stance. The acoustical information will be investigated with respect to their typical frequency spectrum. Apart from the frequencies, also the elapsed time of the analysis process is an important parameter. In *acoustic investigation* the information to value soil properties by acoustic patterns should be acquired *only during* the action on the ground to avoid disturbance and noise or dampening. In parallel, significant frequency patterns can help to detect chaotic disturbance like break-through or sagging. The problem in question is to recognize a specific sound related to typical soil early enough. Therefore, acoustic waves are adopted and transformed into electrical signals, amplified and filtered before being transformed by Fourier Transformation into a frequency representation. Such a computational format of the analogue environmental information is only meaningful if the sample rate of scan of the analogue signal is at least twice as high as the maximum of the highest frequency of the signal in question [VHH, S].From a practical point of view it is impossible to test analyse and classify all materials of soil. Even though, if we focus our attention to the sound pattern of the previous successful steps we are able to decide if the following step is sure insecure or risky depending on the signals generated by soil.

Experiment and Evaluation of acoustic Information for Control

The goal of this data analysis will point out characteristic information similar to the investigations in speech recognition, but in this context, events like break-through or sagging depending of material properties will deliver the important information. To evaluate the principle ideas sketched above, first experiments were performed to investigate the basic applicability and usability of acoustical information including the forces acting on surface. The information received during loading and contacting the ground describe important acoustic events like sliding, sagging and break-thorough depending on different materials. The recorded data were analysed off-line. As results of the first measurements , fig. 2 and fig. 3 show acoustical information, generated by a single leg of our robot and represented by sonograms[VHH, S]. The quality of operability also strongly depends on computational functionality and power. Online sensing and evaluation requires a lot of computational time and other resources. Therefore, these requirements in relation to time efficiency have to be investigated and supported by the computational architecture as proposed.

The data generated by sensors make it possible to implement, test, and evaluate algorithms in the domain of scheduling and communication to achieve more predictability and safety in the domain of robotics [RG, NE]. As a first step the applicability of sound as an additional environmental parameter is shown in order to confirm the idea sketched above.

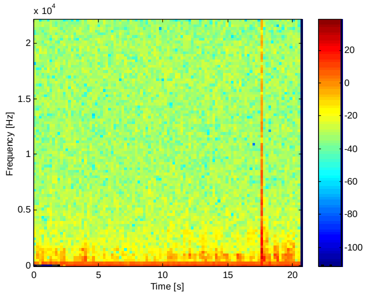

Fig 2: Sonogram of cracking plywood

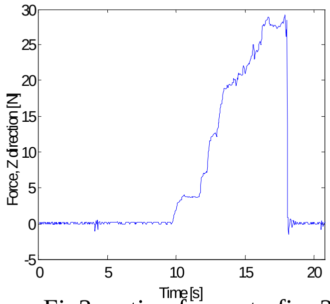

Fig3: acting forces to fig. 2

To conclude, the sketched approach appears to be a promising way to achieve a timely motion of a walking robots, avoiding catastrophic events. Further work will focus on interdisciplinary investigations of material properties, related pattern recognition in acoustics, and the required computational power.

References

[HA] Hartge, K.H;: Einführung in die Bodenphysik; Enke Verlag Stuttgart 1978; ISBN:3-432-89681-6

[ID] Ihme. Th, Deutscher M.; Design and control aspects for six-legged walking robots to realize adaption to environment. CLAWAR 2001, 24.Sept. 2001; Karlsruhe/ Germany.

[KO] Klein, A; Olson, W; :Use of Force and Attitude Sensors for Locomotion of a Legged Vehicle over Irregular Terrain.; The International Journal of Robotics Research, Vol2, No2, 1983, MIT

[LAU] Lauron II; A robotic platform created by university of Karlsruhe and modified by Department IVS/EuK; Otto-von-Guericke University; Germany

[NE] Nett, E. Real-Time Behaviour in a Heterogeneous Environment? in Third International Workshop on Object-oriented Real-time Dependable Systems. 1997. Newport Beach,

[RG] Rajkumar, R., M. Gagliardi, and L. Sha. The Real-Time; Publisher/Subscriber Inter-Process Communication Model for Distributed Real-Time Systems: Design and Implementation. in First IEEE Real-Time Technology and Applications Symposium. 1995.

[S] Shannon, C. E.: Communication in the Presence of Noise. In: Cloane, N. J. A.; Wyner, A. D. Eds.): Claude Elwood Shannon: Collected Papers. Piscataway, NJ. IEEE Press, 1993, pp. 160-172. ISBN 0-7803-0434-9

[SF] Sonic Field Studio; Workshop on Music and Acoustics, December 2002, 53 456 Neuenkirchen, Germany; http://www.sonicfield.de

[SGS] Stein, G; Gillner, S; Selverston; ;"Neurons, Networks, and Motor Behaviour"; MIT Press 1999 ; ISBN: 0-262-19390-6

[VHH] Vary, P.; Heute, U.; Hess, W.: Digitale Sprachsignalverarbeitung. B.G. Teubner Verlag Stuttgart, 1998. ISBN 3-519-06165-1