SP-5115

EL.4.3. GERADOR DE FUNÇÕES COM MICROPROCESSADOR 8085 E INTERFACE DIGITAL/ANALÓGICA

AGUILAR, M.A. - Aluno da FEB.
CRUVINEL, P.E.*; MORAES, E.S. - Professores da FEB, Avenida Aeroporto,389
*Pesquisador da EMBRAPA.

Este trabalho é uma contribuição ao desenvolvimento de instrumentação baseado em pesquisa com "software" do processador 8085. Em particular, foi desenvolvido "software" com objetivo específico de gerar sinais, tais como triangular, senoidal, quadrada, trapezoidal, dente de serra e pulsos. Estes sinais podem apresentar variação de frequência e de amplitude, definidas pelo usuário.

Foi utilizada a porta 22H do circuito integrado 8155 (PPI) e por esta razão houve a necessidade de programá-lo inicialmente como porta de saída.

A interface Digital/Analógica é constituída por dois circuitos integrados SN74LS08, uma malha de resistores R-2R e dois amplificadores operacionais BIMOS CA3140 de alto slewrate e impedância de entrada da ordem de 1 $T\Omega$.

Os circuitos integrados SN74LS08 foram utilizados como chaves entre a porta 22H do 8155 (PPI) e a entrada do conversor Digital/Analógico.

Estas chaves desempenham a função de isolar a porta de saída do circuito integrado 8155 (PPI), a qual é ligada à entrada do conversor Digital/Analógico, fornecendo assim, um nível de tensão de entrada com menores variações.

Este trabalho recebeu apoio institucional do INTEC.

IC/84/35
INTERNAL REPORT
(Limited distribution)

International Atomic Energy Agency
and
United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

À Biblioteca da UEPAE/S.Carlos
Silvio Crestana
Trieste, Agosto 84

STATIC AND DYNAMIC 3 DIMENSIONAL STUDIES OF WATER IN SOIL USING COMPUTED TOMOGRAPHIC SCANNING +

S. Crestana *, S. Mascarenhas **
International Centre for Theoretical Physics, Trieste, Italy,

and

Roberto S. Pozzi-Mucelli
Istituto di Radiologia dell'Universita' di Trieste, Italy.

MIRAMARE - TRIESTE
March 1984

+ Work supported by CNPq and FINEP.

* Permanent address: Departamento de Pequisa - ASPAB, Instituto Tecnologico e Cientifico "Roberto Rios", FEB-Barretos, SP, Brasil - 13560.

** Permanent address: Departamento de Fisica de Ciencia dos Materiais, Instituto de Fisica e Quimica de Sao Carlos, USP, Sao Carlos, SP, Brasil 13560.

ABSTRACT

Previous work of Petrovic, Siebert and Rieke(1) demonstrated the possibility of using X-ray transmission computed tomography (CT) scanning for soil bulk density analysis in soil. We show in the present work that CT can also be used for the measurement of water content in soil. In our case we also show that CT can be applied to measure and follow dynamically the motion of water in soil in 3-dimensions. Further, more inhomogeneities of water content and motion in soil can be observed with this technique. Using a third generation CT scanner several different techniques can be applied such as differential, real time and spatial distribution scanning modes. A linear dependence was demonstrated for the Hounsfield Units (HU) used in CT and water content. The use of CT for water content and motion in soil in 3-dimensions opens new possibilities in this area of investigations.

INTRODUCTION

The study of water content and motion in soil is of fundamental importance in soil science. In the past, several methods have been applied for the measurements of water content in soil such as gamma-ray absorption neutron probe technique, direct water content evaluation by weighting and drying and others (see for instance refs.2 and 3). Only gamma-ray absorption and neutron probe methods may be used for dynamical studies of water in soil. All of these methods do not take account of soil inhomogeneities and do not evaluate three dimensional profiles of water content and motion. Recently, Petrovic *et al*(1982) demonstrated the use of CT scanning for soil bulk density analysis in 3-dimensions (1). CT scanning provides excellent possibilities for spatial and time studies of water content in soil.

Petrovic *et al* mention that they have been unable to obtain consistent results for measurements of

soil moisture by CT. By using a third generation CT scanner (GE CT / T8800) and using an advantageously appropriate choice of parameters such as extended scale, differential level scanning and judicious choice of window-value we have been able to obtain reproducible and quantitative information on 3-d space and time scanning of water in soil.

A complete review of all the aspects of CT scanning can be found in reference (4). A very interesting and instructive introduction to CT may be found in the Nobel Award Address given by A. M Cormack (5). Essentialy the problem of CT scanning is the following: Penetrating eletromagnetic radiation such as X or gamma-rays are absorbed and/or scattered by matter and the expression:

$$I = I_o \exp - \mu x$$

may be used to evaluate the emerging intensity I of the radiation beam of incoming intensity I_o after traversing a sample of homogeneous material of absorption coefficient μ and thickness x. When the material is not homogeneous, such as the case of a sample of real soil or a part of the human body, the more general expression

$$I = I_o \exp - \int f \, ds$$

may be used where f is now a distribution function for the varying absortion coefficient along any direction s across the sample. The central problem of CT is the obtention of the distribution function f (as a function of position for any direction in the sample) when a sufficiently large number of absorption measurements along different scanning directions s has been performed. The image of the object is then obtained as a map of absorption coefficients μ for any desired section (slice) of the sample. This process is performed mathematically with the help of computers and is called image reconstruction technique. In his original work Cormack demonstrated all the necessary mathematical theorems for image reconstruction. He was also able to build a very simple CT scanner, which incidentally may be "revived" for soil science applications as we propose in this work. G. N. Hounsfield developed independently the reconstruction theory and also the first commercial CT scanner for medical use (6). Essentialy in the video of a CT scanner a plot of the attenuation coefficient μ is shown on a gray level viewing system in the so called Hounsfield Units (HU) usually taken to be the following (4)

$$H = 1000 \frac{(\mu - \mu_\omega)}{\mu_\omega}$$

where μ_ω is the attenuation coefficient of water. For the plotting a relative scale is sometimes used where μ_ω is taken as a reference level arbitrarily considered as zero.

ABSTRACT

Previous work of Petrovic, Siebert and Rieke(1) demonstrated the possibility of using X-ray transmission computed tomography (CT) scanning for soil bulk density analysis in soil. We show in the present work that CT can also be used for the measurement of water content in soil. In our case we also show that CT can be applied to measure and follow dynamically the motion of water in soil in 3-dimensions. Further, more inhomogeneities of water content and motion in soil can be observed with this technique. Using a third generation CT scanner several different techniques can be applied such as differential, real time and spatial distribution scanning modes. A linear dependence was demonstrated for the Hounsfield Units (HU) used in CT and water content. The use of CT for water content and motion in soil in 3-dimensions opens new possibilities in this area of investigations.

INTRODUCTION

The study of water content and motion in soil is of fundamental importance in soil science. In the past, several methods have been applied for the measurements of water content in soil such as gamma-ray absorption neutron probe technique, direct water content evaluation by weighting and drying and others (see for instance refs.2 and 3). Only gamma-ray absorption and neutron probe methods may be used for dynamical studies of water in soil. All of these methods do not take account of soil inhomogeneities and do not evaluate three dimensional profiles of water content and motion. Recently, Petrovic *et al*(1982) demonstrated the use of CT scanning for soil bulk density analysis in 3-dimensions (1). CT scanning provides excellent possibilities for spatial and time studies of water content in soil.

Petrovic *et al* mention that they have been unable to obtain consistent results for measurements of

soil moisture by CT. By using a third generation CT scanner (GE CT / T8800)and using an advantageously appropriate choice of parameters such as extended scale, differential level scanning and judicious choice of window-value we have been able to obtain reproducible and quantitative information on 3-d space and time scanning of water in soil.

A complete review of all the aspects of CT scanning can be found in reference (4). A very interesting and instructive introduction to CT may be found in the Nobel Award Address given by A. M Cormack (5). Essentialy the problem of CT scanning is the following: Penetrating eletromagnetic radiation such as X or gamma-rays are absorbed and/or scattered by matter and the expression:

$$I = I_0 \exp - \mu x$$

may be used to evaluate the emerging intensity $\underline{I}$ of the radiation beam of incoming intensity I_0 after traversing a sample of homogeneous material of absorption coefficient μ and thickness x. When the material is not homogeneous, such as the case of a sample of real soil or a part of the human body, the more general expression

$$I = I_0 \exp - \int f \, ds$$

may be used where f is now a distribution function for the varying absortion coefficient along any direction s across the sample. The central problem of CT is the obtention of the distribution function f (as a function of position for any direction in the sample) when a sufficiently large number of absorption measurements along different scanning directions s has been performed. The image of the object is then obtained as a map of absorption coefficients μ for any desired section (slice) of the sample. This process is performed mathematically with the help of computers and is called image reconstruction technique.In his original work Cormack demonstrated all the necessary mathematical theorems for image reconstruction. He was also able to build a very simple CT scanner, which incidentally may be "revived" for soil science applications as we propose in this work. G. N. Hounsfield developed independently the reconstruction theory and also the first commercial CT scanner for medical use (6). Essentialy in the video of a CT scanner a plot of the attenuation coefficient μ is shown on a gray level viewing system in the so called Hounsfield Units (HU) usually taken to be the following (4)

$$H = 1000 \frac{(\mu - \mu_\omega)}{\mu_\omega}$$

where μ_ω is the attenuation coefficient of water. For the plotting a relative scale is sometimes used where μ_ω is taken as a reference level arbitrarily considered as zero.

indicated by numbers 1, 2, 3, 4 from top to bottom of column.
Fig. 4 we show a plot of the variation of water content as a function of time for the different regions. In fig. 5, for the same system and configuration we show a very instructive curve obtained from the data of experiment of fig. 4 by plotting the differences of water content for different regions 1, 2, 3 and 4 as a function of time. It is seen that in ROI-boxes number 1 the water content remains constant quickly (in about 15 sec.) for ROI-boxes 2, hetero-geinities can be seen from the CT-scan but the average water content increases with time and attains a smaller average value. For region 3 there is a continual increase in water content with a more drastic relative change. Finally, like region 1, which attained a constant value in region 4, where the water did not yet arrive, there was no change in attenuation.

DISCUSSION AND CONCLUSIONS

From the previous results it is seen that CT scanning has many potentialities for soil science. From these preliminary results it is also seen that many aspects still need to be developed. One of the first is connected with instrumentation itself. We are performing soil science investigations with an instrument that was specifically designed to be used for medical purposes for human beings. In principle a much more simple instrument can be developed. For medical CT the limitations of dose to the patient impose severe restrictions on the mode of operations of the system. For instance the radiation exposure and thus tube conditions of operation, like kV and mAsec are correspondigly limited. Patient motion and positioning is another limitation which again imposes particular aspects on the design and functioning of CT-scanners. Obviously for the case of soil science, such restrictions are not necessary. Also image reconstruction does not need to be made on line like in our case. Another important aspect is connected with the radiation quality itself. Most CT-scanners for medical applications have a supporting software for image reconstruction based on a small range of radiation quality (spectrum). If the kV to the tube is changed the spectrum is changed and the software does not correct any longer for many artifacts known to be present in CT. For instance it might prove to be advantageous to use higher kV. In our case we have used 120 kV and in fact in many cases we have worked at the limit of power of the system. Higher kV might allow larger columns to be used and eventually provide better contrast in images. Another preliminary limitation of our experiment is that we did not perform classical soil science experiments with standard columns and accessories but improvised due to limited experimental conditions in the hospital. However in this preliminary study various basic conclusions could be obtained, and are summarized below:

b) CT scanning can be used for dynamical (real time) studies in soil, including the measurement of water speeds as large as 1.6 mm/sec.;

c) CT scanning can be used for the obtention of information on hetero geneities of water content and 3-d information by the use of the slicing technique as used in this work or by the obtention of complete 3-d reconstruction from that data (not presented in this paper);

d) Simultaneous spatial and time distributions of water content can be obtained by the use of appropriate CT techniques as demonstrated in this work.

Mini CT scanners costing less than US 7000 have been built for dedicated applications like archeology and wood analysis (7) and we are starting to construct a simple system in Barretos, SP, Brazil, for soil science applications in which many of the limitations mentioned above will not be present. Of course the ideal method for water observation would be NMR CT scanning and we are presently investigating this problem in our Lab. at the Inst. of Phys. Chem at S. Carlos with the help of H. Panepucci and coll.

ACKNOWLEDGEMENTS

The present work was done under partial support of the ICTP - Trieste which provided a fellowship for one of the authors (S.C.). Special recognition are due to Prof. A. Salam for his warm suport as well as to Profs. G. Ghirardi and L.Bertocchi at ICTP. It is interesting to observe that this work was performed during the workshop on Med. Physics held at ICTP, 1983 immediately after the Soil Physics College held at ICTP, 12 Sept. to 10 Oct. 1983 and directed by Profs. D. Gabriels and E. Skidmore to whom we are indebted. We are also indebted to Profs. K. Reichardt and G. Vachaud for discussions during several phases of the present work. Finally we want to thank Professor L. Dalla Palma, Director of the Istituto di Radiologia della Universita' di Trieste, for his generous support to this work.

REFERENCES

1. Petrovic, A.M., J.E. Siebert, and P.E. Rieke. 1982. Soil bulk density analysis in three dimensions by computed tomographic scanning. Soil Sci. Soc. Am.J. 46:445-450.

2. Taylor, S.A. 1972. Physical Edaphology the physics of irrigated and non irrigated soils. W.H. Freeman and Company, San Francisco. 249-293 p.

3. Vose, Peter B. 1980. Introduction to nuclear techniques in agronomy and plant biology Pergamon Press. New York. 328-360 p.

"Technical aspects of Computed Tomography". The C.V. Mosby Company, St.Louis.

5. Cormack, A.M. : Nobel Award Address: Early two-dimensional reconstruction. Med. Phys. - 7(4), Jul./Aug. 1980.

6. Hounsfield, G.N.: Nobel Award Address: Computed medical imaging. Med. Phys. - 7(4), Jul./Aug. 1980.

7. Cesareo E. (private communication).

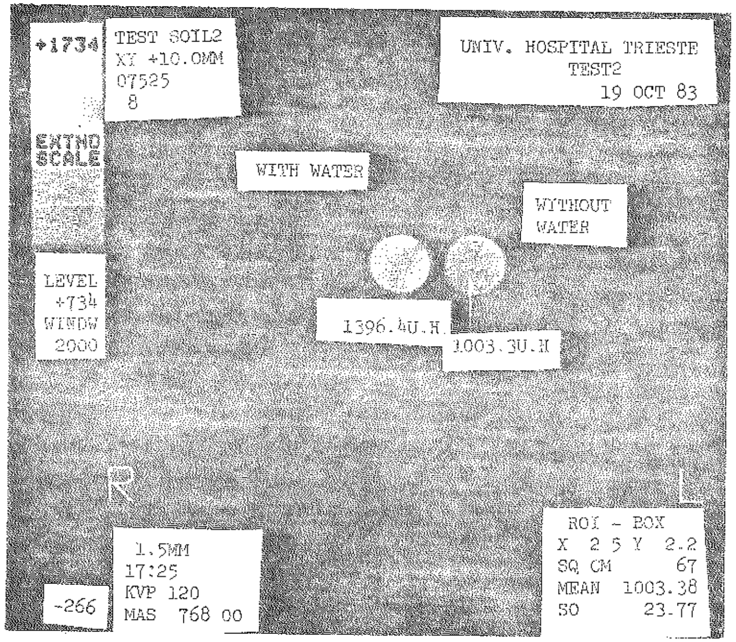

Figure 1 - Appropriateness of the use of CT for water content measurement.We show the differences of two samples with water and without water and the associate values of the water content measured in H.U. (Hounsfield Units).

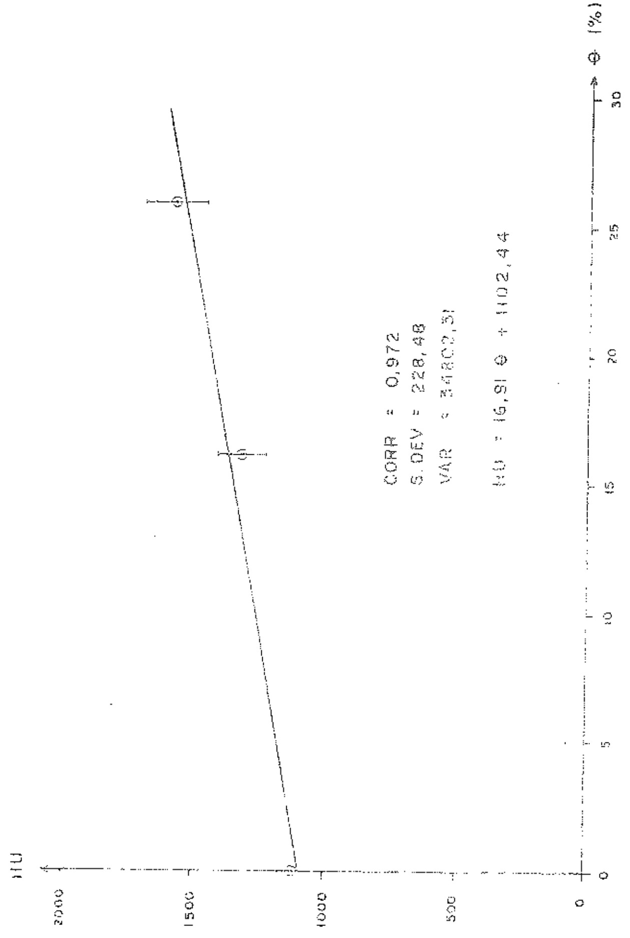

Figure 2 - Linear Calibration curve of Hounsfield Units (H.U.) as a function of water content (θ) (volume of water per volume of soil).

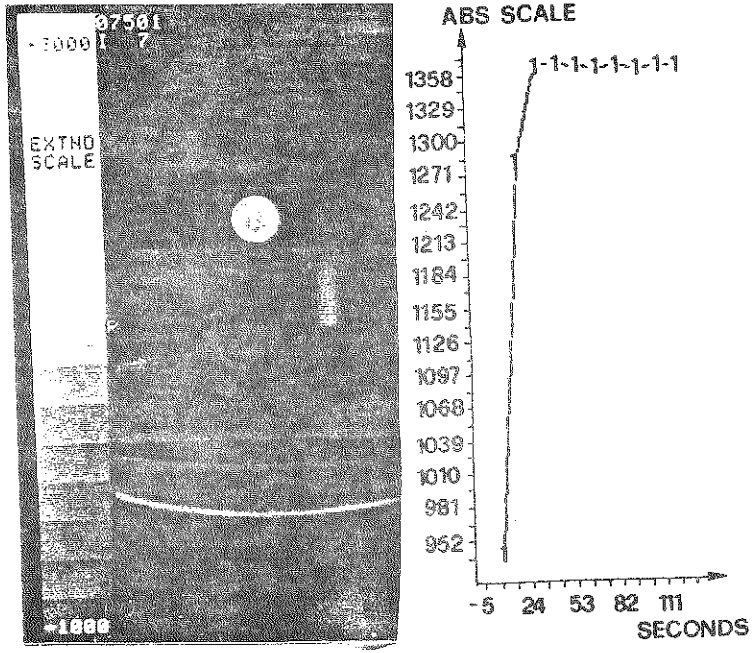

Figure 3 - Dynamical experiment made with a horizontal column showing a fixed slice where sequential scans (absolute scale in H.U.) as a function of time after the introduction of water in the column. The number 1 represents the position of the slice and the size of the area.

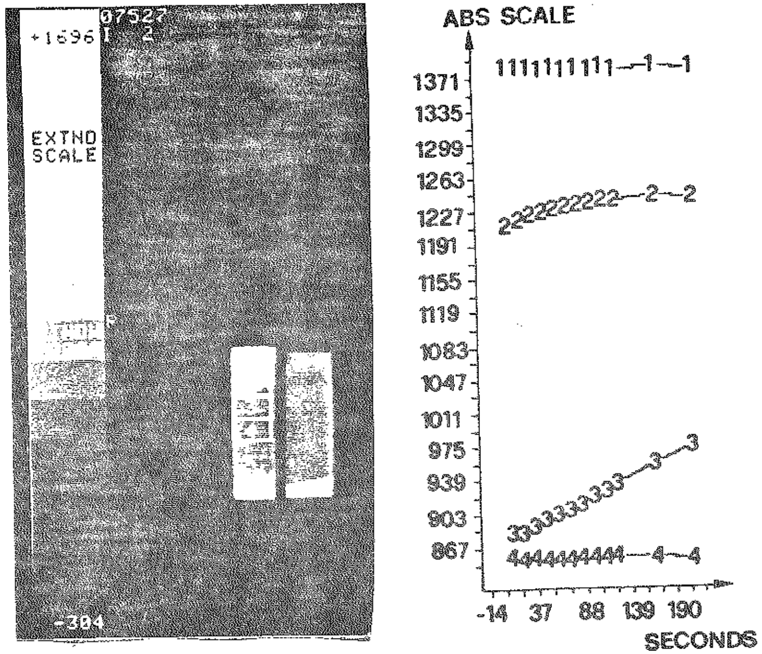

Figure 4 - Spatial and real time (dynamical) measurement made with a vertical column (left side) at different time intervals. The attenuation was measured in different regions with the ROI (Region of interest) boxes indicated by numbers 1, 2, 3 and 4 from top to bottom of column. On the right side we plotted the variation of water content as a function of time for the different regions.

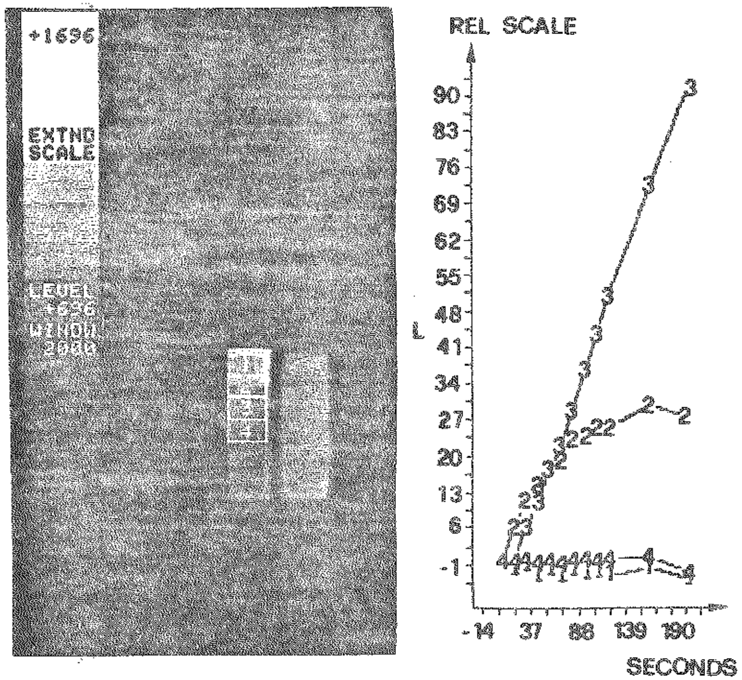

Figure 5 - With the same system described in fig 4, we plotted above the differences of water content for different regions 1, 2, 3 and 4 as a function of time. In the region 3 for instance, we see a continual increase in water content with a more drastic relative change.