ALGORITHMIC ECHOLOCATION

Documentation and Draft Proposal
from
soundplots and medialabmadrid
to
ZKM
Madrid September 2002
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Algorithmic Echolocation

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Objective
Components

- Primary data
- Search modes
- Rendering modes
  - Dramaturgy
  - Interfaces

Theory

- Perception, knowledge engineering , ignorance engineering.
- Avoiding mistakes and or finding truths modes of play. Echolocation and termodynamics.
- Ergodicity, phase transitions, interfaces and long range correlations.
- Inertial subrange in fully developed turbulent flow
- The cone of propagation of causality and similarity
- Navigation in the cheese diagram. Algorithms for direct and reverse echolocation in elastic fluids.

Tools
Examples

- PinusSaki
- Vostok

Expected Deliverables

- Work plan , late sept 2002
- Working version Jan 2003

<u>Objective</u>

The objective of this project[1] is to develop an algorithmic[2] tool able to explore various types of biogeophysical data and make them available in different acoustic and graphic renderings.

We use the term biogeophysical data meaning values measured in several media that can be dated and positioned in the past. Examples include the Vostok core from Antarctica from which a continuous record of 450 Ky of the chemistry of the atmosphere has been obtained.

Other data measured in coral reefs, tree rings, lake sediments and many other substrates provide hints about the variability in the conditions prevailing on this planet in recent and remote past.

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[1] At this point in time, September 2002, this text is a draft proposal from soundplots and medialabmadrid for a joint effort with ZKM that could/should be operative in some form for banquete in January 2003, then a revised version in spring.

[2] Précisons tout d'abord ce qu'en nous appuyant sur Knuth, nous entendons par le terme d'« algorithme » —nous disons également , « procédure ». Il s'agit d'une suite finie d'opérations dénuées d'ambiguï té, à exécuter dans l'ordre dans lequel elles se présentent, parfois interrompues par des décisions à prendre, laquelle part de valeurs données et produit des valeurs cherchées. (Chemla 2002)

The main aim is to make the relevant features inscribed in these records available to our observation and study.

One relevant feature is the very dynamic nature of these records, the varied distribution of power over a range of scales. This dynamic range can be well described in terms of distribution of spectral power over a range of frequencies or wavelengths.

Other relevant features are the intrinsically multivariate nature of the processes under consideration, and the simultaneous occurrence of events at many scales.

The exploration will focus on the identification of covariance in dynamic patterns.

Given a certain window of observation for a variable or set of variables (limited by resolution, magnitude and origin), the point is to perceive , observe and simulate the distribution of variance, the harmonic distribution of power that describes the sequence.

The generality of a limited number of distributions to describe the macroscopic properties of ensembles of microscopic events is a central component of any perception and simulation.

It would be interesting to acquire some experience on the perception side of different distributions shapes in different media such as sound , graphics, stuff. To develop a framework where coherent navigation is possible over a wide range of scales it is important that the user has a good feel for shapes of distributions in order to develop perception and simulation capacity.

If one smashes a dozen or two of bottles or pots, and counts the linear dimensions or volumes of the pieces the type of distribution is similar, to the distribution of sizes of earthquakes over a long period at any point[3]. This could be displayed with sound image and other elements.

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[3] Solnes, J. 1997 Stochastic Processes and Random Vibrations. John Wiley & Sons. New York.P55. Many physical problems have to do with the fragmentation of a larger piece of material into many small pieces and also the size of grains of particles in a large collection. A typical example is the size of gold particles in a large sample of gold sand. Many studies of such problems have shown that the logarithm of the dimension of the grains or fragmented pieces from a large sample will approximately follow the normal distribution, that is, if a typical dimension of the particle is called $D = e^{Y}$, $Y = \log_{e} D$ is normally distributed.

In a short paper, Kolmogorof, (Kolmogorof , A.N. 1941 Über das logarithmishe normale Verteilungsgesetz der Dimensionen der Teilchen bei Zerstückelung. Comptes Rendus (Dokaldy) de L'Academie des Sciences de L'URRS, 31(2)) presented and formalized this interesting probabilistic behaviour (see random walk for a similar development) , which might be referred as the Kolmogorov' s law of fragmentation (Zerstückelung)

Following Kolgomorov, let N(t) be the total number of particles at integer times t, t = 0, 1, 2, 3, …, due to fragmentation from a larger piece of material (rock, gold etc). Furhter, N(r,t) is the total number of particles that at time t have a typical dimension (diameter, volume, weight etc), $Q <$ r, that is, the fragmentation of a piece of material of size r can only yield particles that are smaller. Now assume that between times t and t+1, the probability that one single particle of size r is fragmented into n smaller particles in p_n

Similar shapes of distributions occur over very different scale ranges, with different magnitudes. Some features can be scale independent over some range, others are not.

The identification of symmetries over space or time is central in the reduction of information and the construction of abstract forecasts.

Of course time signals recorded in one position if they can be associated with a speed of propagation (of causality) can be translated into spatial patterns.

The objective is thus, to develop an environment where users with different profiles and intentions can produce Interactive Projections of dynamic processes defined over a wide range of scales in space ant time[i] [ii]. The projection will bring the dynamics and variability of several concurrent processes at potentially remote scales to an environment in the cheese range in the shape of image and sound.

This document is organized in the following way, first we describe the components of the prototype environment , then we describe briefly the theoretical underpinnings of this exercise. In the following section we go through the different tools that have been used to solve several kinds of example problems, and finally a sketch of a work program is proposed.

Components

In the following section some basic components of this project are outlined. We introduce first a sample of primary data that can be used as "learning set". Then we describe the approach to the design of a multiplicity of search modes, taking advantage of recent developments in machine learning, data mining and evolutive algorithmics. In the following section we consider the rendering modes including a sketchy dramaturgy and a consideration of interfaces

Primary data

http://www.pages.unibe.ch/data/data.html
http://medias.obs-mip.fr/www/francais/documentation/
http://www.ngdc.noaa.gov/paleo/
Figures 1 and 2 introduce the Vostok core, this is a very important signal. The available data include a series of CO2 and CH4 concentrations and a temperature estimate. The total time is 450 000 years.

Figure 3 displays the changes in sea level obtained from several sources for a period that overlaps largely with the vostok core and includes 4 glaciation cycles..

Figure 4 displays the clear similarities between the vostok signal and the sea level signal.

Figure 5 spectral rendering of the recurrence of el nino events, a more interesting approach than figure 2. (see also Figure 12)

Figure 6 spectral rendering of a sound recording formaly analogous to figure 5 but displaced in the cheese diagram.

Figure 7 a beautiful public domain image obtained from nasa that could be used as base for other maps as figures 8,9 and 10.

Figure 8 an example of the data available for environmental models . In this case the annual emissions of sulphur dioxide, these data can be animated in time from minutes to centuries.

Figure 9. The data from figure 8 are introduced into atmospheric transport data driven by real meteorological data on a 6 hourly time step with a geographical resolution of 50x50 Km and a several (15?) vertical layers. The total simulated deposition of SO2 is displayed here. Iberian, Roman time, medieval and early industrial pollution patterns coud be simulated and compared, also future scenarios. Similar maps are computed for the effects on ecosystems and health of the predicted deposition.

Figure 10. The current population density in europe, this information is of great interest to evaluate the impact of air pollution on health. An historical development of this map could be very interesting.

Figure 11. In this figure we have the timing of the major volcanic eruptions in the past 600 years, this sequence in itself could be the object of a performance/installation, the image

includes also information on the impact (the echo) of these eruptions in the tree rings of the corresponding years. Perturbation and projection

Figure 12. In this figure we can observe the past 150 years of precipitation and seasurface temperature. Previous to 1900 (tan background) the records are anti-correlated. After 1900 (blue background), the records match

Other time series that could be very interesting to explore,

Short fast pulses of action as in photoshinthesis and molecular phisiology

Time development of a virus population embeded in other populations

Time-energy development of motor engine,

Air Pollution Ozone emep database

seasonality stomatal conductance
www.unece.org/lrtap
www.rivm/cce
www.iiasa.ac.at/~rains

house, kitchen,panchishu

The examples given above are small sample of a much larger set of available data. They might be used as initial set.

The potential user profiles will vary from casual entertainment to parameterised input to music and/or imaging including applications in the field of dynamic modelling of the effects of air pollution on health and ecosystems and integrated assessment modelling and visualization of optimisation of alternative strategies in regional and global frameworks.

Search modes

The search modes to explore the primary data collection and to explore the parameter space to establish the desired parametrization of the projection mode will be based on machine learning and genetic algorithms

Recent examples of interesting work include

A Framework for Distributed Evolutionary Algorithms
M.G.Arenas et al 2002, pp 665-675 in
J.J. Merelo Guervos et al (eds) Parallel Problem Solving from Nature 2002. LNCS 2439, Springer, Heidelberg.

This paper describes the recently released DREAM (Distributed Resource Evolutionary Algorithm Machine) framework for the automatic distribution of evolutionary algorithms (EA) processing through virtual machines built from large numbers of individual machines linked by standard Internet protocols. The framework allows five different user entry points which depend on the knowledge and requirements of the user. At the highest level, users may specify and run distributed EAs simply by manipulating graphical displays. At the lowest level the framework becomes a peer to peer mobile agent system, that may be used for the automatic distribution of a class of processes including, but not limited to, EAs.

(..) It provides a framework for the production of evolutionary algorithm systems and systems of evolving agents which use the internet to allow distributed processing in a peer to peer scalalble fashion.

An Evolutionary Algorithm is made of two parts that are almost completely orthogonal: on the one hand are the problem dependent components, including the *genotype structure*, its *initialisation*, the *variation operators* (crossover, mutation and the like) that will be applied on the genotypes and of course the *evaluation* (computation of the fitness value). On the other hand the evolution engine implements the artificial Darwinism part of the algorithm and should be able to handle any population of objects that have a fitness, regardless of the actual genotype. Evolution engines are made up of two steps, the *selection* of some parents to become actual *genitors* and generate offspring, and the *replacement* of some individuals by some offspring to build up the next generation. (p667)

The structure (…) reflects this point of view, and offers four panels to the user: the problem specification panel to define the problem dependent components, the evolution engine panel for the darwinian components, the distribution control panel to define the way the different islands will communicate and the experiment monitor panel, from where the user can run her experiment and view the temporary and final results.

P.Cowling et al 2002
Hyperheuristics: A robust optimisation Method Applied to Nurse Scheduling
Pp 851-860 in J.J. Merelo Guervos et al (eds) Parallel Problem Solving from Nature 2002. LNCS 2439, Springer, Heidelberg.

R. Thomsen 2002
Evolving the Topology of Hidden Markov Models Using Evolutionary Algorithms.
Pp 861- 870 in J.J. Merelo Guervos et al (eds) Parallel Problem Solving from Nature 2002. LNCS 2439, Springer, Heidelberg.

Yong Liu and Xim Yao 2002
Learning and Evolution by Minimization of Mutual Information
Pp 495-504 in J.J. Merelo Guervos et al (eds) Parallel Problem Solving from Nature 2002. LNCS 2439, Springer, Heidelberg.

Peter Weibel 2001
The art of Interface Technology
Pp 272-281 in H.Diebner, T.Druckrey and P.Weibel (Eds) 2001. Science of the Interface.
Genista, Tübingen. ISBN 3 930171-26-0

Hans. H. Diebner and Sven Sahle 2001
On the role of Micro-Macro Transition and Control Processes for Understanding the Interface
Pp 261-271 in H.Diebner, T.Druckrey and P.Weibel (Eds) 2001. Science of the Interface.
Genista, Tübingen. ISBN 3 930171-26-0

Gerold Baier and Sven Sahle 2002
Listening to Chaos: The Aural Representation of Irregular Rythms
Pp 255-260 in H.Diebner, T.Druckrey and P.Weibel (Eds) 2001. Science of the Interface. Genista, Tübingen. ISBN 3 930171-26-0

Hans H. Diebner 2002
A simulating cognitive system with adaptive capability
BioSystems 64 , 141-147.

Hans H. Diebner, Axel A. Hoff, Adolf Mathias, Horst Prehn, Marco Rohrbach and Sven Shale 2002. Towards a second cybernetics model for kognitive systems.
Chaos, Solitons and Fractals 13, 1465-1474.

Practical examples in this context include,

The search for acoustic patterns that help discriminate best different dynamic features of the signal as a function of listener preferences. (e.g I want a valse or a rap from the vostok core CO2 and CH4).

Optimize transformation when travelling in cheese with different pirogues, active and pasive echolocation.

The search of primary data to define objective functions as in the multiobjective otpimization of integrated assessment models

Emission maps
Transport srms
Effects maps

Dynamic modelling of effects and recovery

R-GOUD (Reaching GOals Using Data: Coupling Mining, Learning, and Evolution) [4]

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[4] R-GOUD Coupling Mining, Learning, and Evolution
An expression of Interest submitted in response to Call EOI.FP6.2002

Background. Knowledge is visible as goals are set and reached, and steps toward their achievements are assessed. In the meanwhile, knowledge is fragmented into speci_c expertises, and diluted into overwhelming amounts of data. Therefore, the present Expression of Interest aims at a strong cooperation between three types of experts: experts in knowledge extraction and machine learning; experts in robust optimization; experts in the application domain.

Rationale. The challenge is twofold: on one hand, e_cient realizations in complex domains have to be speci_c; on the other hand, there are many common features between complex problems, typically the need for handling prior knowledge, exploiting/exploring data, and constructing models. The power and generality of the proposed hybrid Learning/Optimization scheme will be demonstrated through the construction of Modeling Assistants in four application domains: Environmental Studies; Public Health; Numerical Engineering; Linguistic Resources. All four domains are relevant to societal and strategic issues.

Contribution. The major originality of the R-Goud EoI is the willingness of computer scientists and application

An other very interesting application concerns the relation of Toxicological databases for persistent toxic chemicals and trophic chain models of different ecosystems.

Design of interactive animated maps of areas and processes (language, vegetation history, air pollution)

Model reduction, ozone impact, fluxes, srms

Rendering modes

The paradigm in terms of rendering modes that we would like to propose is the chamber music format. In our view this format provides a setting in which dynamic patterns are displayed in an atmosphere of complete freedom, there is no linear, dominant discourse, but the simultaneous development of dynamic patterns. These patterns provide a framework, a scaffold on which the participant, musician or public can weave her or his reflection on change and process.

In this context we think that the display of real time spectral analysis of the signal is a very rich mode to achieve several things.

A) an understanding of our astonishing hearing abilities
B) the possibility of taking sound as a complementary interface with data
C) the use of the sound metaphor to describe the perception of multivariate processes with specific dynamics over a wide range of scales.

Dramaturgy

move perturbations in the cheese diagram with different windows

search for perturbations patterns in areas of the cheese diagram with different windows

a perturbation P has a magnitude (m) a spectrum of energy distributed over a range of frequencies or wavelengths (s) and an origin (o)

a projection or tansformation T has an origin (o) a frequency modulation (f) and or an amplitude modulation (a)

a perturbation $P_{(m,s,o)}$ can be projected with $T_{(o,f,a)}$ into a perturbation $P_{(m',s',o')}$. ·

different T have different meaning

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domain scientists to cooperate, and let their methodological commonalities emerge through a multi-disciplinary dialog. Multi-disciplinary approaches are a sure vector for overcoming technical barriers, disseminating knowledge, discovering innovative solutions and allowing technological breakthrough. Among the envisioned bene_ts of R-Goud are an integrated approach of risk assessment (environmental;health; engineering) and action prioritization (optimal policies; experiment design).

the transfer of energy between and the relative mobility among the perturbations and transformations results in constraints and singularities

Interfaces

Theory

Instead of attempting at this stage a structured analytical approach we will use some examples or cases to introduce the reader to the problems and arguments.

Perception, knowledge engineering , ignorance engineering.

We propose to explore ways to describe dynamic processes. It is arguable that one of the important challenges for the biologist, philosopher and citizen of these times , is to overcome and expand from the mechanistic imagery of the Cartesian plenum. The Cartesian plenum is inelastic and assumes instant propagation of similarity and causality, and both are critical limitations to construct useful images of dynamic processes in the wild real from the chloroplast to the vostok core.

There is a continuity of flow matter and energy, the combined action of a multiplicity of processes shape the rather complicated network of events that resonate in the perception of a bang or a cheese. The successive impacts of multiple inputs of energy over a wide range of scales agitate the turbulent cascade of mater. In the cool region of the universe we play in matter binds and unwinds in fluid viscous intermittent pulses in and elastic medium.

We want to argue that we are in a position of limited knowledge and limited power, our understanding of events is limited by our individual or cooperative capacity to discriminate and remember. The fabrication of knowledge is a distributed process.

A the concept of a limited capacity to organize networks of learning (perception and memory) embedded in a cascade of energy and matter can apply to describe the neural networking in brain models, the design of the rail network, the evolution of metabolic pathways and migratory habits.

Distribution of power in earthquakes
Distribution of sizes of the pieces of a broken pot
Distribution of sizes of pots and tools in a kitchen
Distribution of sizes of pots and tools in a farm
Distribution of words in a text, notes in a piece of music
Distribution of sizes of plankton patches, clouds
Distribution of exososmatic and endosomatic incomes,
Distribution of lifexpectancy and body size

Forms of distributions , intermittence and tone

Modes of propagation of similarity and causality, the dynamic landscape

The mechanistic imagery framed in the inelastic cartesian plenum is faulted by the intermittent nature of the distribution of power in the perturbations. The turbulent flow of matter energy and information unfolds, broadcasts and perceives in an elastic medium. And events and perceptions are not smoothly distributed. This roughness or unsmoothness of the distribution of energy and matter is evident over many scales, the consideration of ways to display and relate to the complicated nested networks of distributions is useful and helps in identifying patterns and processes resulting from to the limited speed of propagation of similarity and causality and to the simultaneous occurrence of events at many scales.

We can imagine the navigation in the cheese diagram in terms of echolocation.

We are a perturbation that propagates and are impacted by the projection of other transformations.

The propagation speed is variable and depends on the nature of the perturbation

From light to sound to chemical diffusion and population dynamics the range of speeds at which causality and similarity propagate vary from thousands of kilometres per second to a few meters per glacial cycle.

In the relatively fast range , from our point of view, is sound.

We will explore echolocation as metaphor , the roles of the Doppler shift in resolving uncertainty provide a very useful insight into practical uses of active perception in an elastic medium. Active perception in an elastic medium (APEM) . An elastic medium can be smooth and rough and is capable of potential and gradients.

"*Echolocation is an active process in which sense organs of an animal respond to energy that is radiated by the animal itself*" (Pye 1983).

"animal" can be generalized to any entity capable of learning , or any ensemble thereof

"radiated" can be generalized to include the establishment of long range correlations by projecting trough phase transitions and other symmetry breaking events. This means the simultaneous operation of several speeds of propagation. Multiconality

Echolocation is an active process in which sense organs of "an entity capable of learning or any ensemble thereof" respond to energy that is radiated "in several media" by the entity itself.

"*Any sound that returns as an echo is subject to three kinds of change, all of which can yield information about the reflecting target. The echo is effectively a copy of the emitted signal that is delayed in time, changed in frequency and reduced in amplitude*". (Pye 1983)

Any perturbation that returns as an echo is subject to three kinds of change, all of which can yield information about the reflecting target or responding entity.

The echo is effectively a copy of the emitted signal that is delayed in time, changed in frequency and reduced in amplitude,

A active source emits a signal and receives an echo.
From the echo the source knows about target range and relative speed
If we anticipate the time delay, the frequency change and amplitude change we predict , identify the forcing landscape. (the responding elements of)
Organizing time delays, frequency changes and amplitude changes over existing underlying signals is a common feature of all active sources.
The presence of time delays, frequency changes and amplitude changes indicates the potential presence of an active source modulating the combined signals .
Counter measures
The resonance of perturbations across phase transitions, (gas,liquid,solid) changing instantly the speed and magnitudes of the transformation that projects perturbation P in to P'

(…) the ideal velocity – measuring signal has a long duration and a constant frequency (cf), characteristics that are very poor for range measurement. Such pulses are produced by bats and cetacea.

It is important, however, to realize that the Doppler shift is primarily a change in the time scale of the echo.

A change in time scale can be described as a doppler shift.

The change translates into relative position (range) and velocity as well as finer details once these features are "removed"

If the target is approaching the echolocator the end of the pulse is reflected after a shorter roundtrip than the beginning: the reflected pulse is compressed in time, raising its frequency and also reducing its duration .

If a perturbation is compressed in time the relative distance to the feature on focus or target is approaching. If a pulse is expanded in time the target is receding, the relative distance increasing, we are leaving.

Time compression in roundtrip signals is a way to simulate changes in relative position of the target landscape.

The paired impulses of Rousettus and most Aerodramus swiftlets illustrate this point well. Each impulse is capable of registering the range of the target which may change in the interval of 20 ms or so between their separate arrivals. But the pair sounds as a unitary click to the human ear and can also be considered as a single pulse of 20 ms with zero amplitude for most of its duration. After reflection the internal interval is changed by the Doppler shift and can thus indicate relative velocity without any actual frequency shift being measured. (Pye 1983)

Secondly, a net advantage would be obtained by bats that emit echolocation sounds of low intensity – a hitherto somewhat puzzling characteristic of many species. While the bat experiences the inverse of the fourth law for its echoes, the moth is warned by one way propagation of the same sounds which are only subject to the inverse square law. If this seems paradoxical, consider a sixteen-fold increase (+ 12 dB) in the bat's emitted intensity: the bat will then detect the moth at twice the previous range but the moth will receive a *warning at four times the previous distance. Whatever these respective distances might be, sufficient reduction will work in the bat's favour until it might actually achieve first detection. The effectiveness of this stratagem (low intensity pulses) depends on the bat's ability to find sufficient prey within such a small radius and on its agility in catching at short notice.*

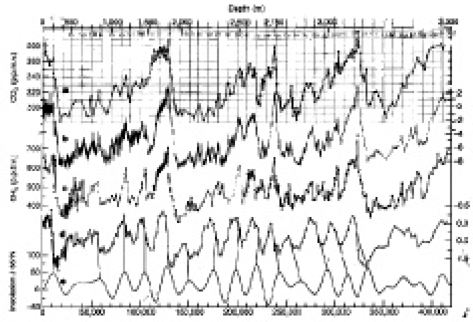
the ideal velocity – measuring signal has a long duration and a constant frequency (cf), characteristics that are very poor for range measurement. Such pulses are produced by bats and cetacea.

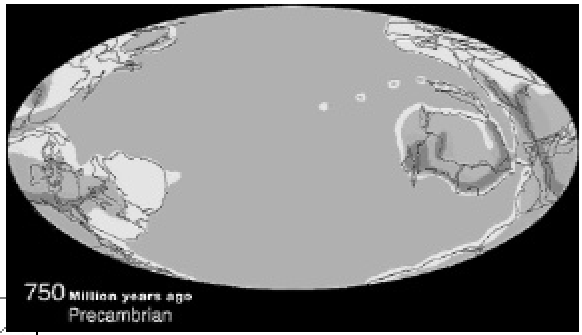
So a signal that we can anticipate is an echo that contains information about our relative position, our course to target .

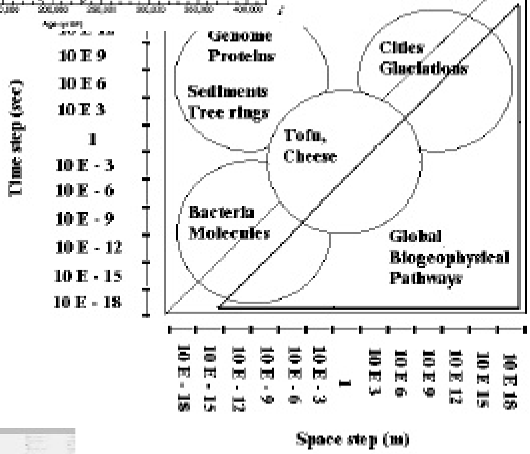
Navigation in the cheese diagram

Algorithms for direct and reverse echolocation in elastic fluids.

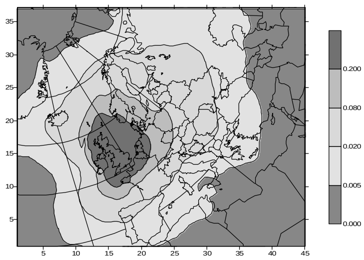
Distribution
Magnitudes
Amplitude modulation
Frequenciy modulation
Red shift, blueshift
Scaffolds and webbs,

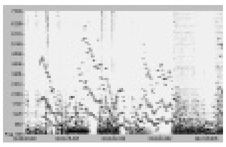






PCP_1990_UK ng/m3



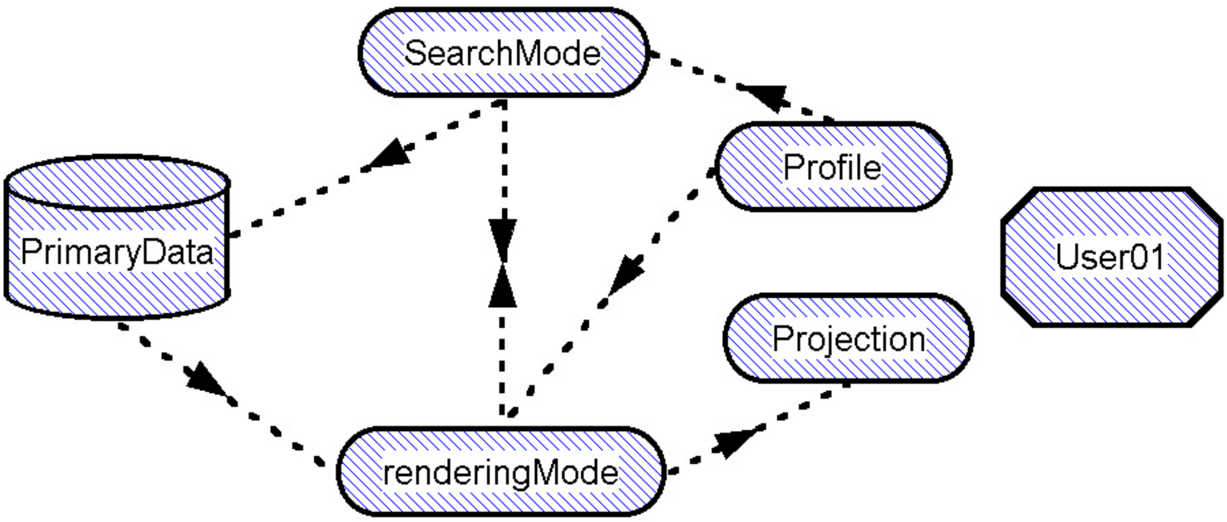


Cheese, aug2002 soundplots

Tools

S-plus
Model maker
Virtual waves
C sound
Soundforge
Cakewalk
Coolpro
Spectral lab

Examples



Profile

Think of the user as a perturbation and try to find the relevant echo in the landscape provided by the primary data

Position range size range satisfaction range

SearchMode

Registration

Evolutionary search

Define the pulse that elicits an echo (doppler shifted for position and size) from primary data wall (landscape)

Rendering mode

Echo phrased and filtered after profile

Sound, image, text, other

Primary Data

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Expected Deliverables

Work plan , late sept 2002
Working version Jan 2003

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