INTELLIGENT PARAMETRIC PRODUCT MODELING SYSTEM AS NEW PARADIGM FOR VISUAL THINKING PROTOTYPING IN REAL-TIME CONTROL

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Intelligent Parametric Product Modeling System (IPPMS) is the new basic philosophy in conceptual parametric object-oriented design based on visual prototyping and fractal homogeneous parametric network . This is the "thinking" environment for the process design, control and discovery which gives the conceptually oriented knowledge representation and knowledge management approach implemented by means of heuristics. It allows to realize rapid visual thinking prototyping for real-time control strategies using artificial neural network, fractal algorithms and homogeneous transformation based on the new approach with a wide variety of learning genetic algorithms created from graphical specifications associated with algebraic notation.

Keywords: Image Recognition, Prototyping, Parametric , Network, Real - time, Control systems, Intelligent systems

1. INTRODUCTION

The objective of this research is to develop better theoretical and practical methods for using image understanding technologies based feature-based modeling and conceptual parametric object-oriented design of material processing technology, control and discovery for an automated scan plan generation system, modeling real-time control systems and planning process. This is new technology for building automated support for many aspects of process/control modeling and rapid electronic prototyping that simulates an expert in the performance of a task and allows to produce the product of higher quality and it is delivered in less time and at lower cost.

2. RELATED WORK

Previous work based on feature-based modeling for design and control can be classified as classical approach based on CAD system using features as integrating elements linking design and manufacturing (LeClair, *et al.,* 1996; Wu and Liu, 1996), parametric and variational geometry (Bronsvoort and Jansen, 1993), 3D object reconstruction from dimensioned orthographic views (Dori and Weiss, 1996), Hough transformation (Hough, 1962), neural network and genetic algorithm (LeClair, *et al*.,1995). In perspective it can be used also the technology of the on-line measurement based on the homogeneous transformation theory (Lin and Tsai, 1996), fractal and chaos theory (Barnsley and Sloan, 1996) , interval method.

Virtual Prototyping as new paradigm provides dependency tracking and full geometric associatively for feature based design/control (Blair *et al.,*1998). For this goal, Technosoft Inc. offers an Adaptive Modeling Language (AML) that supports high-level object- oriented design (Blair *et al*.,1998). Computer Aided Prototyping System (CAPS) developed in NPS provides also automated support for many aspects of software prototyping using Prototype Specification Description Language(PSDL) based on maintaining consistency between graphical views and algebraic notation of a design (Luqi and Barnes, 1989). PSDL provides for specifications of control and data flow and based on the following mathematical model (Luqi and Barnes, 1989) :

$$G = (V, E, T(V), C(V)) \qquad (1)$$

where a composite node's implementation is graph - G. V is the set of vertices associated with edges E, maximum execution time-T(V) and control constraints-C(V) associated with V. This work shows how to automatically generate suitable ground equations from non-ground equations of the query.

However, engineering methods and procedures that encompass both geometric and non-geometric objects, require a level of human-like intelligence for understanding of this problem which current methods do not support. Most of the existing systems can execute the direct developer instructions and cannot help him in abstract thinking. In addition, many methods assume that the data input is provided in a specific mode or order that there is need for manual input of constraint information and programming..

Extending on these said works it is important to note that there is needed fundamental work to automatically generate suitable control strategies from feature-based visual model in the query using formal parametric graphic specifications and the visual thinking.. Visual thinking is needed to provide the necessary understanding of the physical phenomena for control process and a graphical model can also be used to represent and reason about the task of unsupervised learning the parameters, relation ships, weights, and structure of each of these representations.

3. GENERAL METHODOLOGY AND PROCEDURE

3.1 Algorithm of global control strategies

Extending on PSDL model (Luqi and Barnes, 1989) it is needed to develop the new discrete dynamical systems (Fig. 1) as high-level computational systems with graphic implementation and a combination of heuristics:

$$G=[V, E, T(V), C(V), X_i(V), Y_i(V), Z_i(V), \mathbf{A_i(V)}, HF_i(V), P_i(V), PF_i(V), BD_i(V), TO_i(V), W_i(V), PB_i(V), G_i(V), SB(V)_i] \qquad (2)$$

where $X_i(V)$,$Y_i(V)$,$Z_i(V)$ are coordinates of vertices of vectors associated with V; $\mathbf{A_i(V)}$-homogeneous transformation matrix using Denavit-Hartenberg notation (Lin and Tsai, 1996), $HF_i(V)$-heuristic functions and rules, $P_i(V)$-parametric constraints,$PF_i(V)$-parametric function; bias distance-BD(V), $TO_i(V)$-text; $W_i(V)$- connection weighs; $PB_i(V)$)-local feedback function, $G_i(V)$-genetic code.

The structure of IPPMS is a tree consisting of atomic and composite nodes (Fig.1). IPPMS allows automatically to transform each formal parameter and arithmetical operations from graphic specifications of CAD systems, algebraic notation, ground equations and non-ground equations into primitive vector-prototype of fractal homogeneous neural network in according with the homogeneous transformation matrix $A_i(V)$. The relative position and orientation of frame $[(X(V)Y(V)Z(V)]_i$ with respect to frame $\mathbf{[}(X(V)Y(V)Z(V)]_{i-1}$ (Fig.1), can now be expressed by the following homogeneous transformation matrix :

$$A_i = \prod_{i=i+1}^{V} T_{xi}, T_{yi}, T_{zi} \prod_{i=i+1}^{V} R_{\alpha i} R_{\beta i} R_{\gamma i} \prod_{i=i+1}^{V}, S_{xi}, S_{yi}, S_{zi} \qquad (3)$$

where $\mathbf{T_{xi}, T_{yi}, T_{zi}}$ are the translation matrices for the distance with the constraints of A, B, C, L and a bias distance-$BD_i(V)$,$\mathbf{R_\alpha}$, $\mathbf{R_\beta}$, $\mathbf{R_\gamma}$ are the rotation matrices respect to $X_i(V)$, $Y_i(V)$,$Z_i(V)$ axes and $\mathbf{S_{xi}}$, $\mathbf{S_{yi}}$, $\mathbf{S_{zi}}$ are the scale matrices.

The general concept and procedure of IPPMS (Fig. 1, Fig. 3) consist of the followings steps :

- to create the IPPMS file based on Visual Thinking Conceptual Parametric Prototyping Language (VTCPPL) with visual and text information or use visual information of scanned image or realize model based file of CAD systems .
- to convert and transform of any raster graphic formats of scanned image into 3D vector CAD formats using mechanisms of effectively homogeneous fractal tree interpreting visual images. The image is divided on segments of the irregular form using of standard receptions of image processing such as selection of edges and texture analysis of image .
- to generate a homogeneous network of nodes , each of which can be constructed of a finite number of V possible states in discrete time according to IPPMS model (2) with local identical interaction rule (see Fig. 1 , Fig. 3); $HF_i(V)$-heuristic functions and rules, $P_i(V)$-parametric constraints, $PF_i(V)$-parametric function . This method is founded on self-similarity of atomic and composite prototypes and consists in modeling of figure by several smaller fragments of itself (Fig. 1). The special equations known as affinities allow to transfer, rotate and scale of sites of transformations respect to global and local of coordinates systems

using matrix (3).

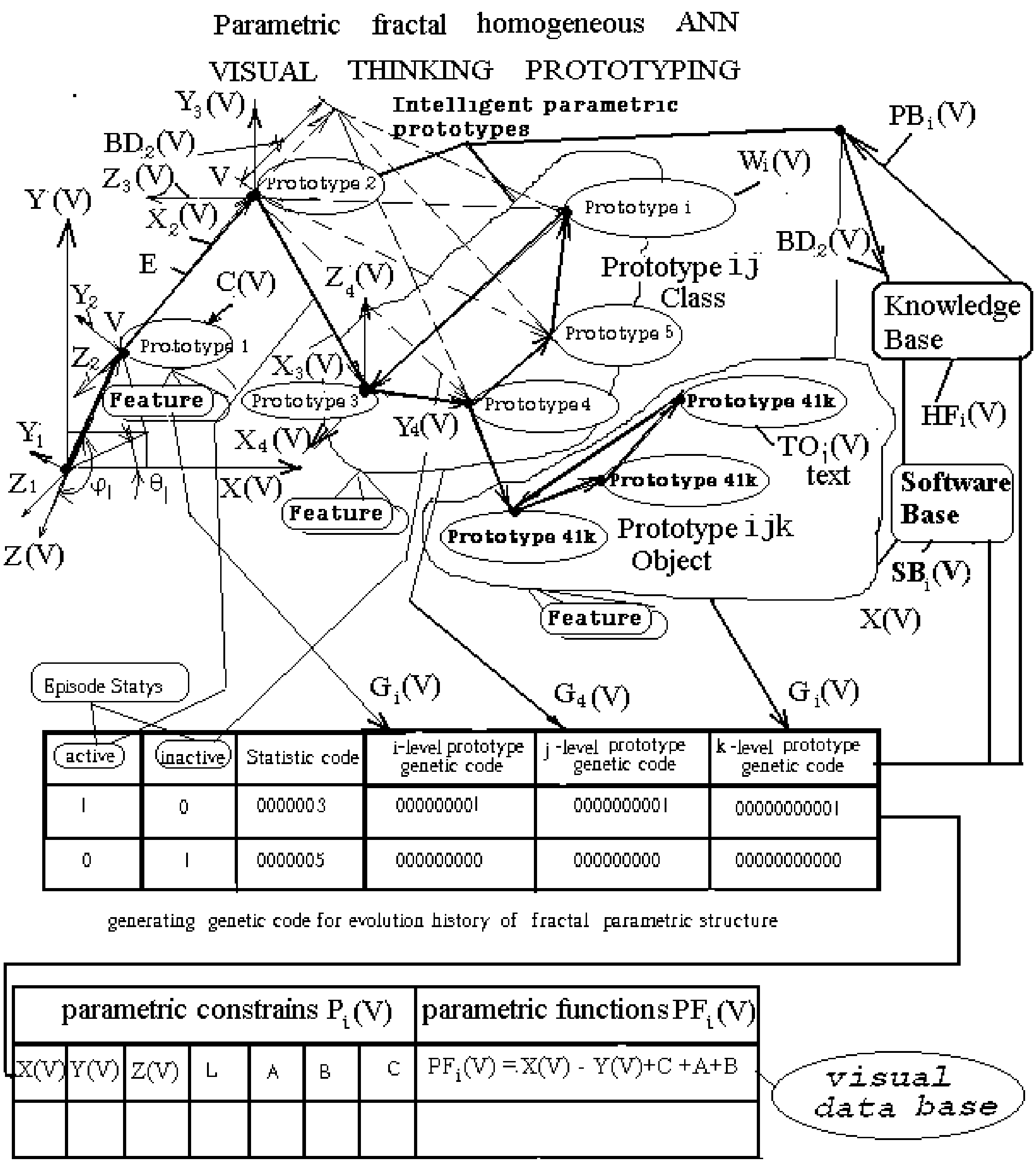

Fig. 1. A schematic representation of IPPMS control strategies. The model generates the fractal tree using a family of homogeneous matrices. A key step in the structural recovery is the formation of . cellular encoding with genetic code of each node of fractal network.

- to build initial 3 D or m-vector parametric model based on Geometric Modeling System and model (2) with parametric function-$PF_i(V)$ and parametric constraints-$P_i(V)$ using both IPPMS graphic specification and the full automatic transformation from other CAD systems.
- to change a sites of nodes of a homogeneous lattice according to control constraints C(V), the parametric constraints $P_i(V)$, a definite heuristic rules and heuristic functions-$HF_i(V)$ involving the values of its nearest neighbor, where the position of sites around each vertices are determined relative to local system of coordinates. To transform of the parametric constraints $P_i(V)$ or C(V), IPPMS uses the global control heuristic for all nodes of model such as a bias distance (feedback)-BD(V) associated with local system of coordinates (Fig.1).
- to determine and evaluate the several possible parameters of lattices of neighborhood structures for this step respect to global system of coordinates using both the homogeneous transformation matrix **$A_i(V)$** and heuristic functions-HF_i (V) with learning parametric function of geometric objects (Fig. 1).
- to calculate new coordinates of vectors associated with V using the homogeneous transformation matrix $A_i(V)$ again.

- to convert of atomic prototype into many-level concept's system developing the intelligent parameterized prototype-classes and prototype-objects using on object-oriented analysis and composition of system.;
- to make the automatic logical dimensioning check or dimensional chains and relations-ships to the composite prototype . Dimensioning check is making with computing the requisite links of the network vertices.
- to repeat all steps (consecutive or concurrent) for all vertices of a network with computing both W(V)- connection weighs and G (V)- genetic code (chromosome).

IPPMS consist of a homogeneous network of sites with each site taking on one of possible values. The sites are updated according to a definite rule that involves a neighborhood of sites around each one. IPPMS is simple system that exhibits very complicated behaviour based on Visual Thinking Conceptual Parametric Prototyping Language (VTCPPL) that provides for specifications of both control and data flow and based on the hierarchical how-level logical model.

3.2. Image recognition algorithm

To identify objects , it is necessary to investigate the topological interrelation ships between the different features and to transform raster image in vector to receive semantic and syntax information of a high level that is defined on the basis of their topological , geometric and functional characteristics as the abstract model associated to the feature. Hough was the first to come up witch a practical algorithm suitable for detecting collinear point (pixel) arrangements in (X,Y)-coordinate (image)space by proposing a voting systems (Hough , 1962). The coordinate values (X,Y) of each pixel are inserted into the line equation Y = aX+b, thus defining a line in (a, b)-parameter space.

Now many developers of software products use Hough's transformation in the applications. . However, this traditional approach has essential disadvantages 1) Low accuracy and speeds in decision making; 2) It allows not to employ a small set of generic operators such as high-level descriptions of structure, behavior, control actions, classification, and localization to perform bi-directional mapping between the information-rich field and the abstract spatial thinking.

The new effective heuristic algorithm for image recognition, understanding image and its conversion in 2D/3D CAD formats is proposed. This algorithm includes both connection's mechanism, parallel data processing and logical inference mechanism for intelligent parametrized classes

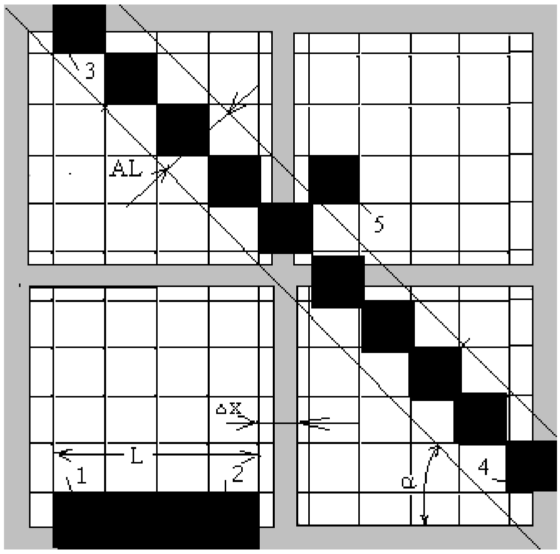

Fig . 2 Example of vectorization procedure using heuristics based on the segments of frames of the regular form .

and objects creation. This algorithm allows a user to full automatically define a model composed of mechanical features from a set of 3D surface points. Computer vision techniques is based both 2D data and 3D data using non-contact, three-dimensional position digitizes and camera as the potential for fast and exact aiding the process and models produced from sensed data that are useful for manufacturing operations (Fig. 2, Fig. 3).
The algorithm works as follows (Fig.2, Fig. 3):

- The scanned image is divided on two dimensional segments of frames of the regular form (for example as 16 x 16 grid) using receptions of image processing such as selection of pixels set grouped on intervals of boundaries of neighboring frames via evaluation of its positional (X, Y), color (r, g, b) and textural parameters (ΔX-width of an interval of vertical/ horizontal borders , that is considered as fuzzy tolerance , see Fig. 2).
- Second step involves creating a set of vectors, each of which contains points are corresponded with intervals set for vertical/horizontal borders. and a set of heuristics that .are used to reduce complexity of vectorizing the images (for example, see Fig.2., where pixel 1 , 2 are on the line L).
- To create a set of vectors, each of which contains points are corresponded with inclined lines using heuristics with the fuzzy tolerance AL (for example, see Fig. 2, where pixel 3 , 4 are on inclined line L). Taking into account the heuristic rules of fuzzy logic, it is possible to consider with some probability that the point

5(Fig. 2) also belongs to an inclined line.

to create a set of vector models of arc, circles, complex curve lines of the high level for representation of geometric objects using the heuristic rules.

- to repeat all steps (consecutive or concurrent) for all vertices of a network with computing both W(V)-connection weighs and G (V)-genetic code (chromosome) according to above mentioned algorithm (Fig. 1, Fig.3)

The performance of the proposed methods was checked by authors using in many respects of image understanding in CAD/CAM system. This algorithm allows to work in real-time and raises also the speed of processing of the image in hundreds/thousand time.

3.3 Technology direction

A difference between the IPPMS methodology and other systems such as ANN, is that it automatic specifies the feature type, and approximate location without control directions of users based on VTCPPL with intelligent prototyping and dimension-drive strategies. The method uses parametric encoding for a genetic tree structure of the model , of the details /product or process. IPPMS is an array of identically programmed automata or cells which interact with one another based both on local identically rules and high-level rules of VTCPPL

The main difference between IPPMS and conventional ANN is the fact that the inputs are parametrized as automata/cells of fractal homogeneous parametric network and information is only exchanged between several current neighboring cells (neurons). The nodes of this network are associated with parametric prototypes using potential relationships as units are connected to one another via fractal homogeneous transformations. IPPMS knows at any moment of time a situation, relationships and orientation of any cells or prototype in a network and knows control strategy by these vectors based on a genetic code with VTCPPL

Thus this fractal homogeneous neural network is modeled as visual spatial graph using many-level fractal prototypes representation with parametric features (Fig. 3). Any changes on algebraic model put in changes of parametric visual model. .On other hand any changes on visual model are transformed in adequate changes of algebraic model. These points used to calculate a homogeneous transformation matrix (3) that relates the 3-D frame coordinates of a product from its projected position in the image plane (Fig. 3). However, this homogeneous transformation matrix allows to build both parametric fractal ANN that use visual thinking prototype in nodes of network (Fig. 3) and self-directing , self-improving systems for the design/control of material synthesis/processing using inductive and deductive memory.

IPPMS can make more intelligent prototyping system that can full automatically generate the parametric genetic code for planning and evolution of the material process/design , understand feature of parts with greater precision and speed, analyze the dimension, , assemble facts in memory, use knowledge to infer other facts, evaluate, postulate, make decisions, give advice, explain his reasoning and learn.

4. EXAMPLE

Fig. 4. describes the spatial undirected graph of constructing of triangular prism automatically generated from the set of HF_i(V)-heuristic functions and rules, P_i(V)-parametric constraints, PF_i(V)-parametric function and other attributes in

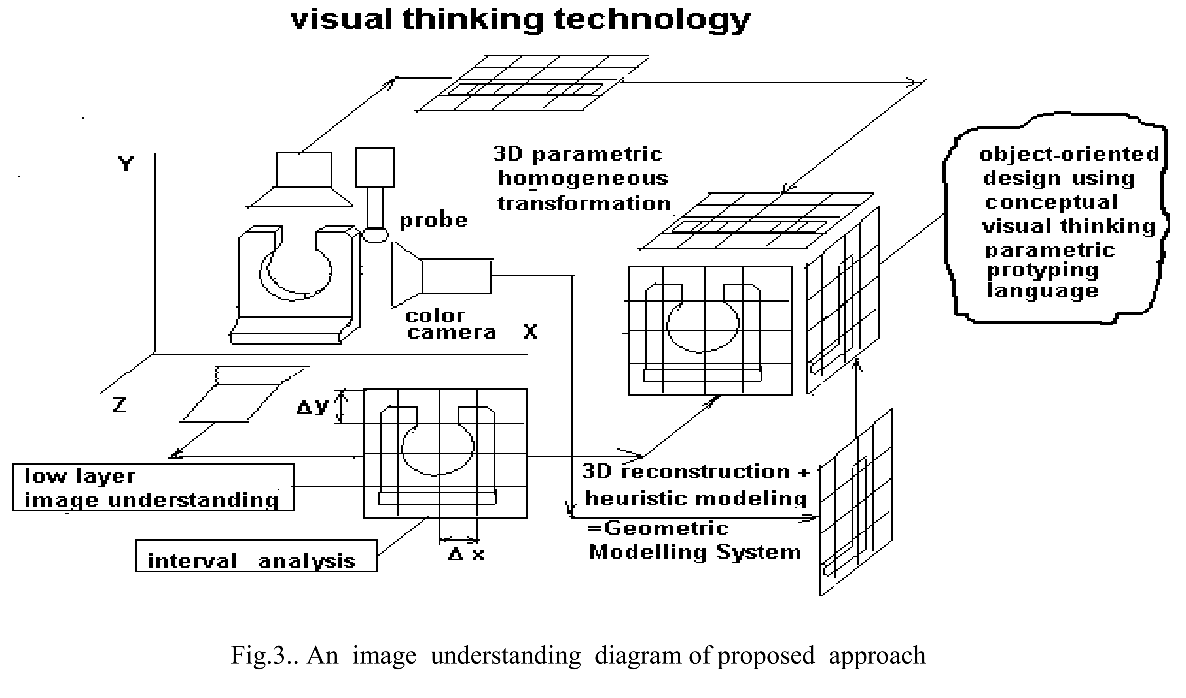

Fig.3.. An image understanding diagram of proposed approach

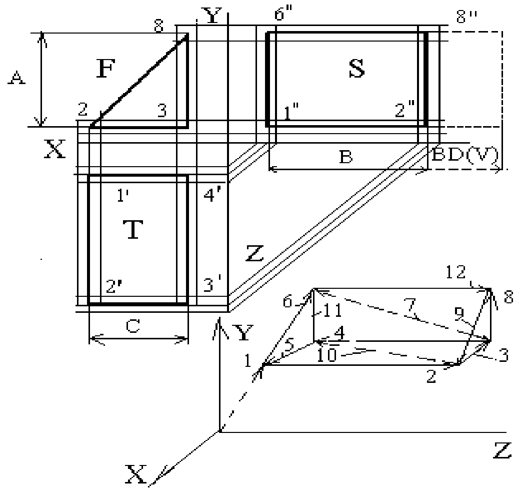

Fig. 4. The scheme for 3D object reconstruction from views using IPPMS.

equations (2) , (3). The graph was full automatically constructed in real-time mode by method described in Section 3.2 using IPPMS algorithm (automatically input of the constraints).

.This example shows that there is enough to represent the parametric spatial model as undirected graph designed only from 6 nodes and 12 edges. It is smaller than in example (Dori and Weiss, 1996) as minimum in 2 time , where is used bipartite graph designed from 24 nodes (10 for of network because front view and 14 for side view) and 34 edge (13 for front view and 21 for side view). It is important to note that in work (Dori and Weiss, 1996) is need to solve 28 equations using variational geometry with Jacobian matrix. (current manually input of 28 equations of constraints). IPPS allows to solve this task in real-time and full automatically using only 12 homogeneous transformation matrix (3) One of the advantages of IPPMS is its ability efficiently to join points from orthographic views in 3D nodes of network because the graph can be build in any sequence and order. The IPPMS graph can also include imaginary edges (for example see the edge 1 (Fig. 4).An example, a node 2 has vertex 2 that is determined via design of set of parameters

$$V(2)=\{X_2(V), Y_2(V), Z_2(V)\}$$

where $X_2(V)$, $Y_2(V)$ are considered on front view F and $Z_2(V)$ can be found via heuristic search in site of intersection of intervals both site view S and top view(Fig. 4). As alternative variant can be considered also $Z_1(V)$ instead of $Z_2(V)$. It can change only the order of generation of model but can not change geometric parameters. IPPMS does not restricted to specific types constraints and can be applied easily and fast to any geometric universe.

5. CONCLUSION

The IPPMS approach has following advantages over current practice: 1) The thinking fractal models of IPPMS are compact and require considerably smaller memory size. This models require less modeling time on several occasions than this time for traditional methods such as parametric and variational design, neural network and genetic algorithm. 2)It allows easily and quickly to simulate and visualize a m-dimensional space with a n-vector attached to each point in the space in according with physic phenomena. 3) It allows to develop graphical formal specification that full associate with the task of learning the parameters, weights, and structure of each of these representations. 4)IPPMS is universal constructor for the control strategies of complex systems based on visual prototyping

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