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Part 2

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Toshio Koga
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Estimation and Prediction of Object-Oriented Segmentation for Video Predictive Coding.

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Abstract

The research proposes a simple finite state image model for estimating video sequence motion field, background memory updating and luminance prediction. The model allows object-oriented segmentation utilizing a fuzzy state (New-Scene) so that state transitions diagrams, modeling the physical constraints can be defined both for image segmentation and for luminance prediction. Preliminary results for integrated image segmentation and displacement fields estimations are presented. The proposed algorithm allows the implementation of video coding schemes where only structural prediction errors have to be transmitted, when physical motion coherence is plausible, and which is suited for completely parallel distributed processing.

1 Introduction.

Motion compensated videocoding requires the estimation of the displacement field which can benefit from structural information of the imaged objects and background. Recent researches and results show the feasibility of both object-oriented segmentation and physically coherent displacement field estimations.

In specific applications where the video camera is fixed and frame rate is low an additional saving of information transmission can be obtained if the uncovered background luminance is already available at both the transmitting and receiving ends; moreover motion compensated image interpolation can benefit from apriori knowledge of background information.

The aim of this research is to define and experimentally evaluate an algorithm for image object-oriented segmentation and displacement fields estimations useful in video predictive coding. Algorithm complexity has been kept as low as possible to limit technology issues and allow parallel distributed processing.

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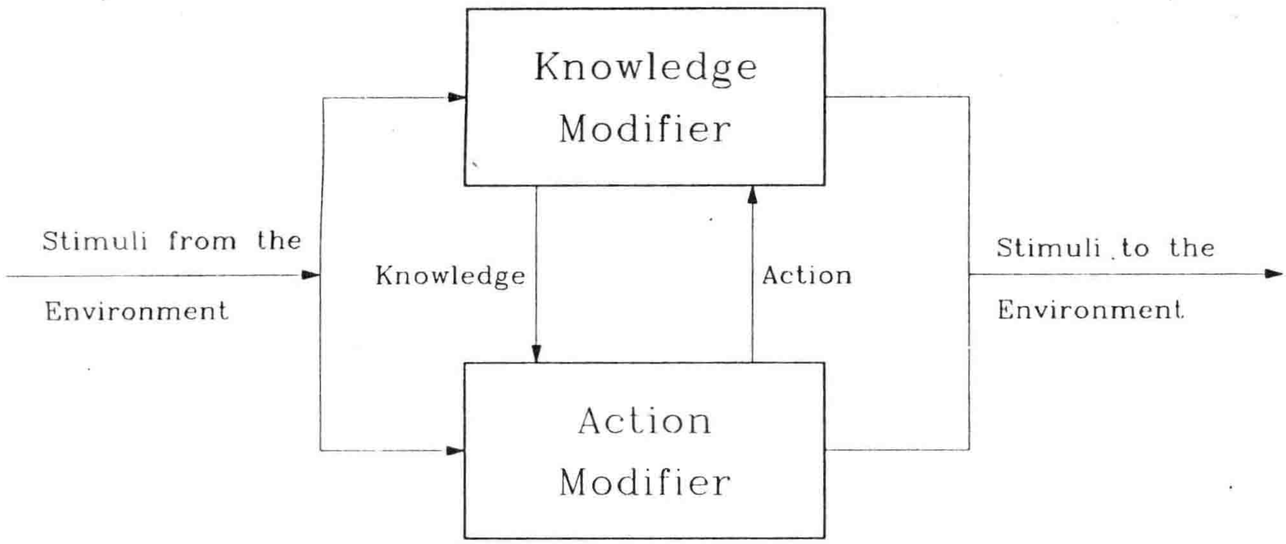

Figure 1: An Action-Knowledge Interaction Model (AKIM).

We propose a recursive algorithm based on the Object-Background model (BONS model) for predictive coding recently proposed and experimented by the authors /2,3/ and utilizing well known displacement estimation techniques /4/.

The algorithm consists of two successive steps: estimation of the present image characteristics (state segmentation and displacement field) and generation of the predictors field. The estimation uses the previously estimated image state field and the predicted displacement field. The results of the estimation are used for the structural prediction of the displacement field so that a structurally coherent predictor field can be defined.

In section 2 the basic operational model is introduced, in section 3 it is applied to the object-oriented moving images segmentation, in section 4 the current experimental results of the proposed estimation technique are discussed and in section 5 a structural prediction technique for videocoding is preliminary presented.

2 An Action-Knowledge-Interaction Model (AKIM).

Most of the intelligent activities require tight interaction of knowledge and action in order to correctly respond to environment stimuli. In fig. 1 a first approximation model of this interaction is shown: it consists of two basic blocks the Knowledge Modifier (KM) and the Action Modifier (AM) both receiving the input stimuli from the environment and updating their output using the information issued from the complementary block. The interaction requires a suitable synchronization depending on the specific modeling. This model, though very rough, is a first step for designing

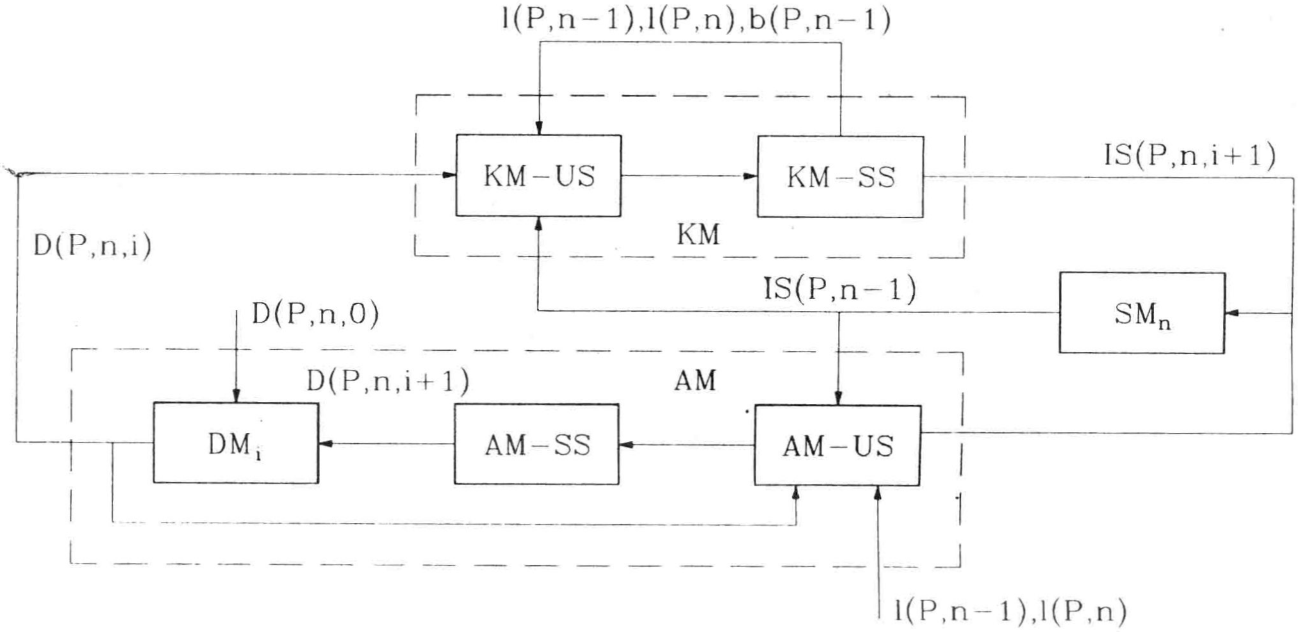

Figure 2: AKIM applied to object-oriented video sequence image segmentation.

complex perceptive processing once the representation of the Knowledge and the Action are defined together with the Modifiers algorithms.

Cognitive sciences suggest and justify many types of useful models, based on neuropsycological experimentations, one of basic results is the definition of the selective attention and orientation concepts which give rise to interacting processes /1/.

3 The AKIM based moving image segmentation.

The AKIM allows the implementation of an algorithm for the integrated estimation of the object-background image segmentation and the displacement field of two successive images in a video sequence. Significative researches are reported in recent literature /5/,/6/.

Fig. 2 shows the top level block diagram of the proposed moving images segmentation algorithm which is presented in this section using a top-down approach. The closed loop of AKIM allows recursive information updating for each image given the results of the previous one using as main input environment stimuli the previous and current image luminances. Action and Knowledge are represented by the displacement and the image state field respectively. The former gives the local displacement while the latter gives the local image state, as proposed by the BONS model.

The image state IS(P,n) defines the segmentation of image n into Background (B) ,Object (O) and New-Scene (NS) areas according to the BONS model defined in /3/, BONS being the acronym of Background, Object and New-Scene, IS(P,n) is therefore a matrix whose elements values (O,B or NS) represent the state of the corresponding pel P at sequence image n.

These information can be used for further image processing such as the updating of the background luminance memory, which can then be considered a secondary environment input.

The structure of the algorithm depends on the specific models adopted for KM an AM, which are presented in detail in the following subsections.

Both AM and KM consist of an Updating Section (US) and a Smoothing Section (SS). The USs require updating data: for AM-US we use the result of the previous recursion stored in DMi (defined as the current recursion displacement field), for KM-US we use the image state resulting from the previous image segmentation state stored in SMn. Both SMi and SMn have to be initialized: SMi is initialized by a first approximation of the displacement field (e.g. block matching displacement estimation), SMn is initialized by the image state at the beginning of the video sequence segmentation process.

The environment inputs of KM-US are the previous and the present image luminances l(P,n-1) and l(P,n) respectively, the background luminance b(P,n-1); the updating input is the previous image state IS(P,n-1) and the current recursion input is the displacement field D(P,n,i) which is generated by the action-knowledge processing, where n the sampling time of the video sequence and i the recursion index. The output of AM-US is the unsmoothed updated image state IS(P,n,i+1).

l(P,n-1) and l(P,n) are also the environment inputs to AM-US which receives also the current recursion displacement field D(P,n,i) and the updated image state IS(P,n,i+1); its output is the unsmoothed updated displacement field D(P,n,i+1). The recursion cycle is iterated until a given figure of merit (f.o.m.) stabilizes within a given threshold; we have chosen the number of displacement vectors as f.om. and a given percentage of unchanged displacement vectors as threshold.

Once the updating recursion is terminated the background luminance in the background memory b(P,n-1) can be updated using the following expressions:

$$\begin{aligned} &\text{if } IS(P,n) = B \text{ then} \\ &\qquad b(P,n) = l(P,n), \\ &\text{else} \\ &\qquad b(P,n) = b(P,n\text{-}1). \end{aligned}$$

3.1 Image state updating and smoothing.

The estimation of the image state IS(P,n) utilizes the BONS model which allows the estimation of IS(P,n) wherever the displacement field D(P,n) and IS(P,n-1) are known using the BONS state transition diagram driven by the luminance differences of Fig. 3. The four prediction differences: spatial deference (SD), frame difference (FD), displaced frame difference (DFD), computed only if $D(P,n) > 0$, and background luminance difference (BD) are computed. The smallest one is used to drive the state transition diagram from the source state defined by the local and known IS(P,n-1).

Because of the recursion we use the current recursion displacement D(P,n,i), while the generated image state is the updated state IS(P,n,i+1) which requires smoothing due to the estimation errors.

A simple majority filter is used to smooth the resulting local image state utilizing structural constraints, in case of parity conditions priority is given to state O.

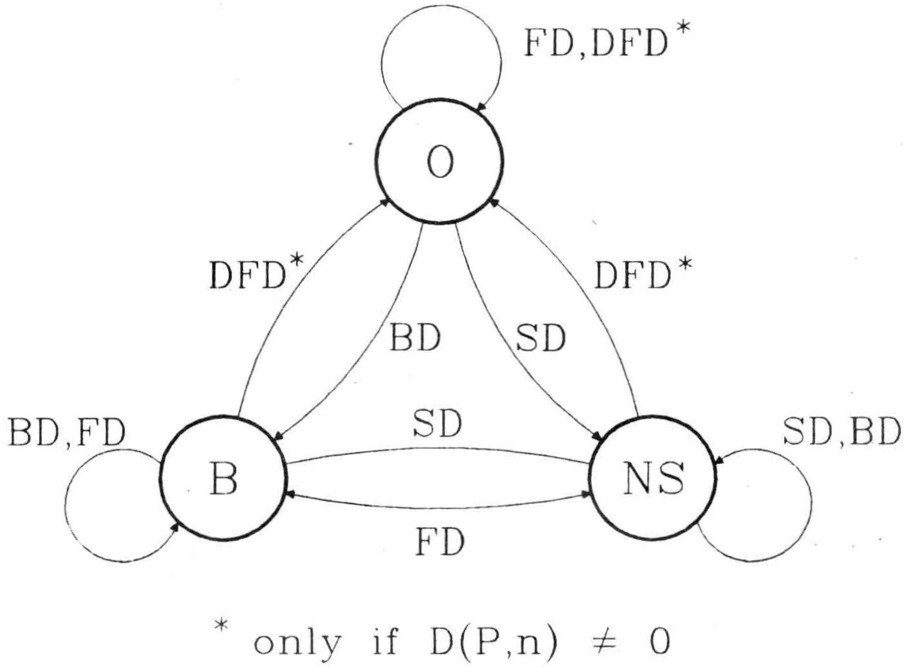

Figure 3: State transition diagram of the Background/Object/New-Scene (BONS) model for image state updating.

3.2 Displacement field updating and smoothing.

The displacement field D(P,n) can be updated by the incremental displacement which minimizes the local prediction errors constrained by the previous and current image state fields.

At each pel whose updated image state IS(P,n,i+1) is O or NS the updating recursion displacement vector D(P,n,i) is used to compute nine updated DFDs using the incremental unity displacements along horizontal or vertical axes, the smallest DFD (constrained by the fact that the source must be O or NS), defines the unsmoothed updated displacement D(P,n,i+1).

The displacement field is then smoothed in the following way:

a) If the four neighboring pels belong all to an Object we assume that a rototraslatory motion is the best approximation and the corresponding FIR smoothing is performed;

$$D(P,n,i+1) = 1/2.D(P,n,i+1) + 1/8.(D(P+x1,n,i+1) + \\ +D(P-x1,n,i+1) + D(P+y1,n,i+1) + D(P-y1,n,i+1)) \quad (1)$$

b) In the other cases the mean value of the displacements of the physically plausible local structures is computed.

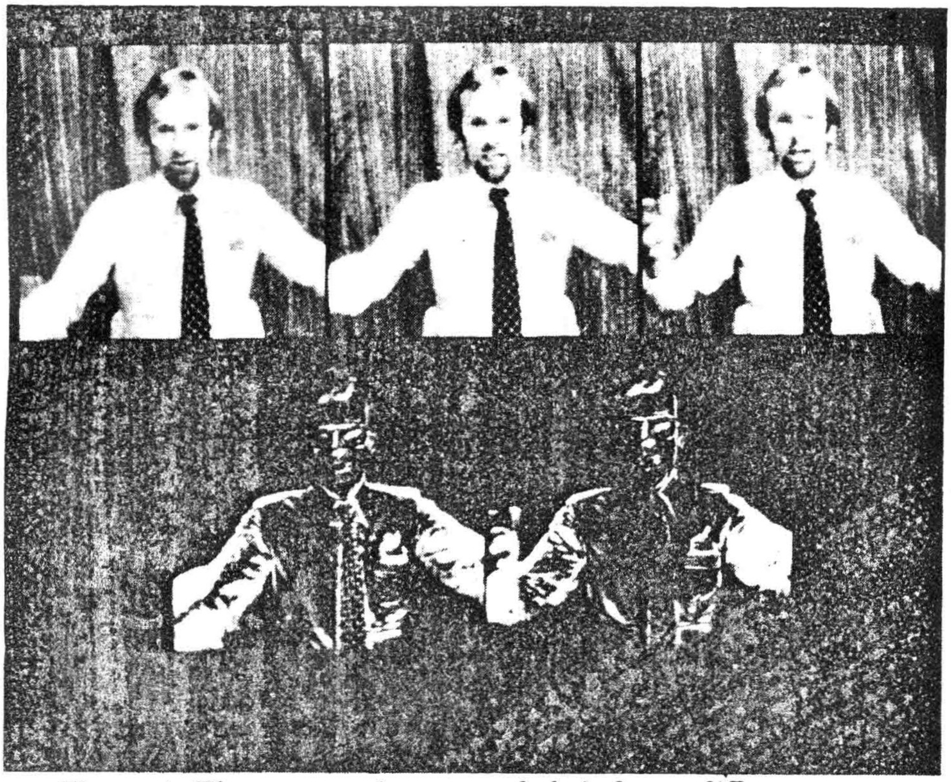

Figure 4: Three source images and their frame differences.

4 Experimental results.

Simulations have been performed on the natural sequence "Trevor" obtaining the segmentation of two successive pairs of images, fig. 4 shows also the luminance frame differences. Fig. 5 and 6 show the block-matching and the proposed object-oriented displacement vector fields respectively together with the displaced frame differences, the updated image state and background luminance, for the two image pairs. Fig. 7 shows the evolution of the image state during recursion.

5 Application to predictive video coding.

The integrated image segmentation can be extrapolated to define the prediction luminances for a statistical predictive video coding algorithm.

Let us assume that the current image fields (state and displacement) are computed at both the transmitting and the receiving end of a coding-decoding video system and that we need the prediction luminances $\hat{l}(P,,n+1)$ for coding the next frame. We can first determine the prediction displacement $\hat{D}(P,n+1)$ from the known D(P,n) and IS(P,n) by inertia using physically plausible constraints and then define $\widehat{IS}(P,n+1)$.

$\hat{D}(P,n+1)$ is the extrapolation of the current displacement field at each pel belonging to the O or NS image state. Wherever the displacement vector divergence is lower than a given threshold displacement interpolation is plausible, it is applied but the resulting displacement field is generally incompletely defined. Displacement extrapolation allows then the definition of the predicting image

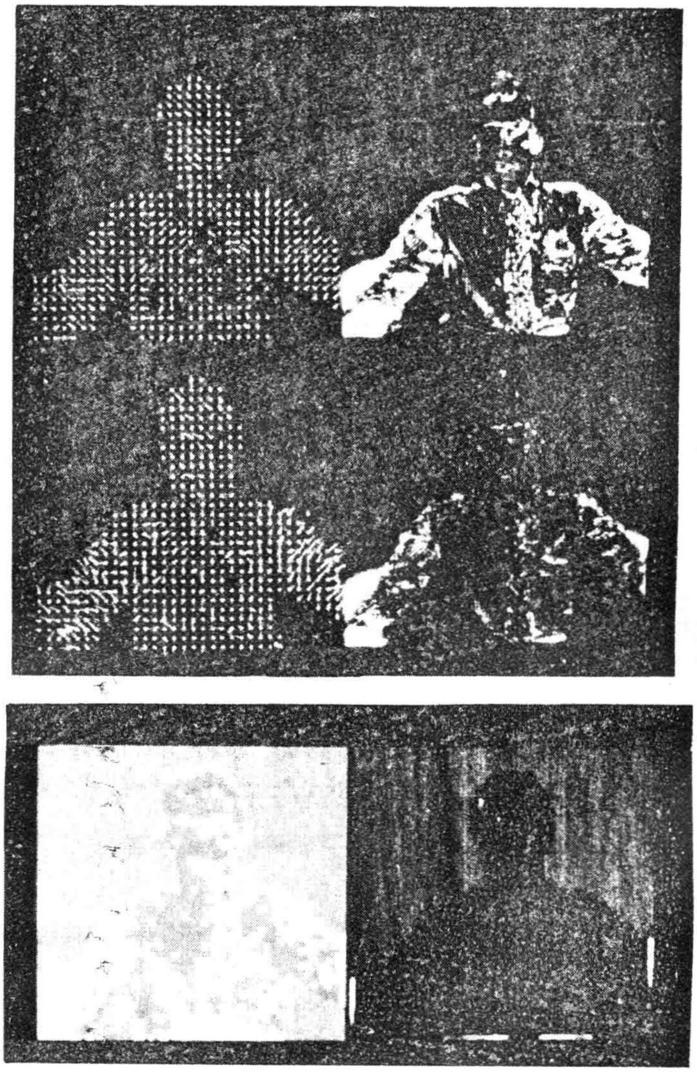

Figure 5: Segmentation results of the first pair of source images:
a) block-matching displacement vector and displaced frame difference fields;
b) object-oriented displacement vector and displaced frame difference fields as resulting from the application of the proposed algorithm;
c) updated image state field and background luminance.

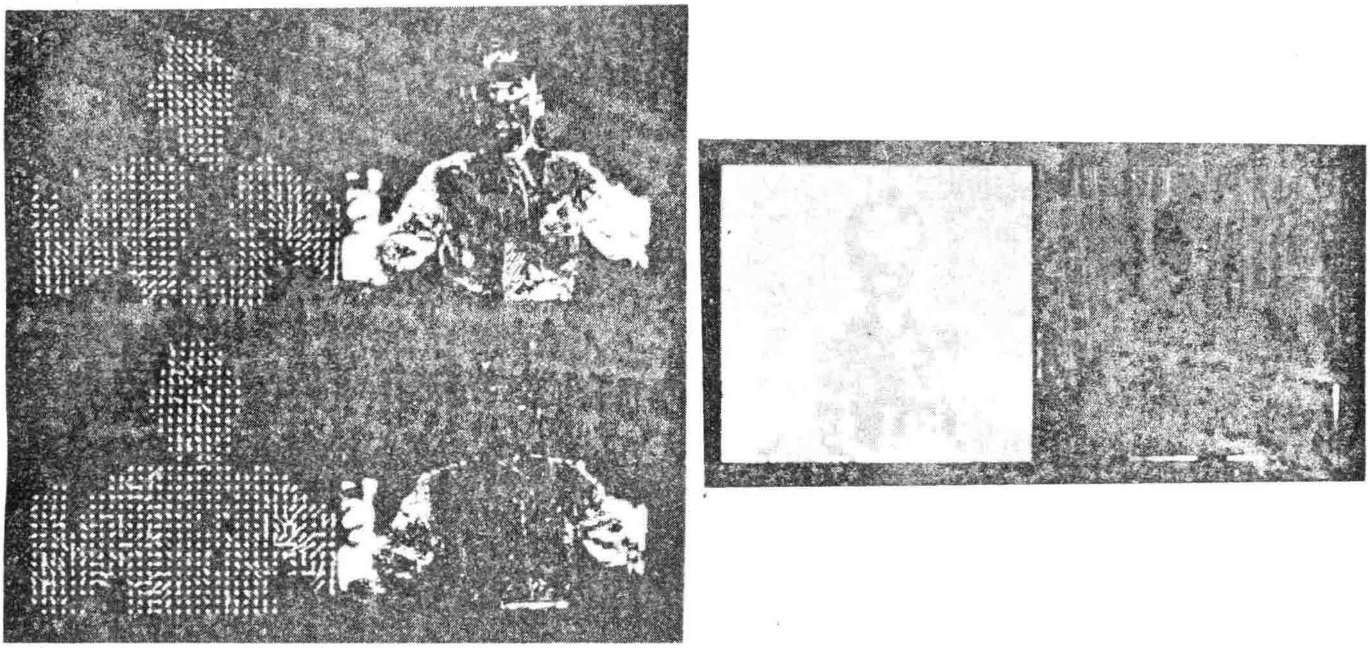

Figure 6: Segmentation results of the second pair of source images: a),b),c) as in fig. 5.

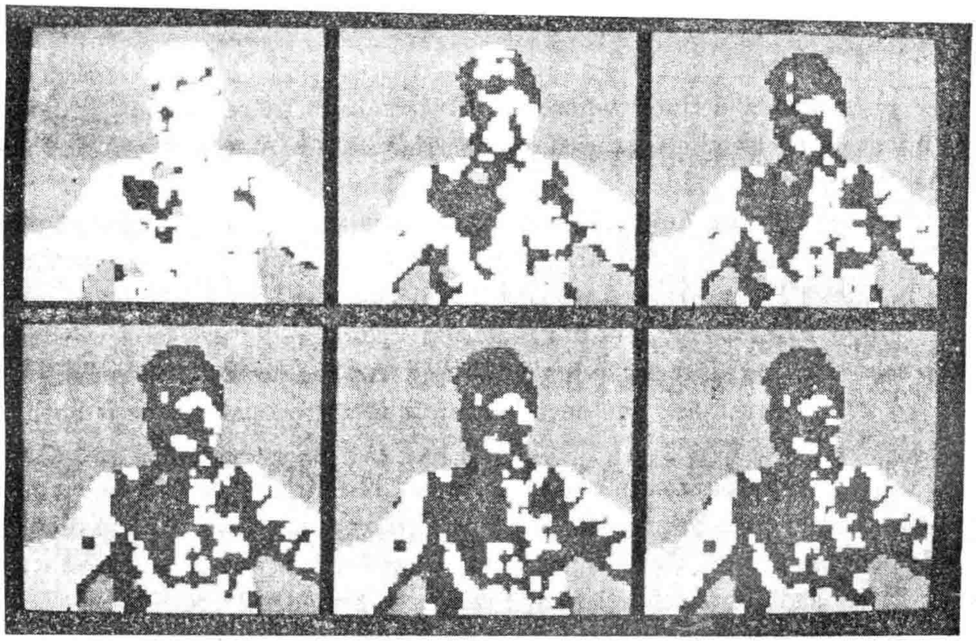

Figure 7: Evolution of the image state during recursion.