Geometry of Change: An Objective Analysis of Dynamic Systems

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1 Introduction

In today's world, people are constantly faced with the need to make decisions under conditions of high uncertainty. Financial markets, economic systems, production processes, even everyday tasks — all of these domains share one thing in common: a complex dynamic that is extremely difficult to predict by simple methods. Linear models and classical indicators, used in most popular analytical systems, provide only a superficial picture of what is happening, often ignoring the multi-dimensional nature and the interconnection of the system's elements.

At the same time, the real world is always multi-dimensional: every movement of an object takes place surrounded by a multitude of factors that exert influence upon it. An attempt to decompose this complexity into separate linear dependencies leads to a distortion of the picture — as can be seen in the example of failed forecasts even by recognized analysts, and of strategies that "broke" under a sharp change in market or environmental conditions. This tells us that we need instruments capable of accounting for several dimensions of what is happening at once, of forming a holistic view of the development of events, while remaining objective and reproducible.

One approach capable of solving this problem is the analysis of changes through the construction of key points that record the extreme states of a system, and of their spatial arrangement relative to one another. At the foundation of such a method lies a rigorous mathematical idea: any complex change can be described through a system of extrema, identified in a certain sequence and confirmed by statistically significant features. Thanks to this, geometric analysis not only makes it possible to understand the current structure of the dynamics, but also provides the ability to forecast the probable development of events with a high degree of accuracy.

Unlike methods based on assumptions or subjective interpretation, this approach minimizes the influence of the human factor. The main goal is to build a mathematically correct model of change on the basis of objective data. It is fundamentally important that such models remain stable under a change in the scale of observation: whether it is a five-minute chart or data spanning several years, the result of an analysis performed according to the same rules will be comparable and commensurable. This property of fractal stability makes it possible to apply the method across any time and price ranges without losing the reliability of the forecasts.

Another advantage lies in the fact that the method is built on fixed rules for selecting the points for analysis. For example, to record an extremum, it must be confirmed by a certain number of preceding and following data points, which excludes the possibility of random outliers and false signals. In combination with the use of several interrelated projections of the data (Planes), this makes it possible to capture the maximum amount of information about the state of the system without distorting the original facts. In other words, each projection reflects only a part of the truth, but taken together they form a holistic understanding of the object's dynamics.

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The application of this approach is appropriate not only for financial markets, where models based on extrema have proven their effectiveness in forecasting trends and reversals, but also for the analysis of any processes subject to phase transitions, abrupt changes, or cyclicity. For example, geometric analysis can be used in econometrics to identify key moments of a change in economic conditions, in production planning to forecast failures and points of overload, as well as in the social sciences to assess the probability of cardinal changes in the behavior of large groups of people.

It is important to note that, despite all the complexity of the nature of the processes being studied, the method itself remains maximally algorithmic: conducting the analysis requires only correctly determining the reference points and constructing the necessary lines — without the application of heuristics or intuitive estimates. This makes it convenient for automation and integration with software systems for data processing, allowing it to be used both in individual analytical work and on an industrial scale.

At the same time, this approach differs fundamentally from most widespread strategies in that it excludes the “curve-fitting” of results to a desired conclusion. The mathematics used does not allow models to be adjusted to the analyst’s specific expectations, but on the contrary forces one to follow only the facts confirmed on the chart or in the data. This is especially important in those areas where an erroneous decision can lead to significant losses, for example in trading, investment, or the management of production processes.

Thus, the goal of this article is not to reveal the secrets of a specific methodology for building models, or to delve into the details of forming lines and points, but rather to acquaint the reader with the basic ideas of the geometric analysis of change and to explain why an approach based on the recording of extrema and their mutual arrangement makes it possible to achieve high forecasting accuracy in any dynamic system. Knowledge of these principles opens the way to a deeper understanding of ongoing processes and forms the basis for subsequent independent study and application of the method in one’s own practice.

Our task is to show that hidden regularities really do exist, and that they lend themselves to precise description if the right instrument is used. Mastering the basic concepts of spatial analysis will help everyone who strives to go beyond primitive indicators and to find a way of understanding change at a deeper level, while preserving the objectivity and mathematical rigor of their conclusions.

2 Mathematical Basis

Any process on the physical plane can be described through the interaction of three obligatory elements: the Object, the Environment, and the Observer. Such a triad forms a dynamic system, in which every change of the Object is recorded and interpreted by the Observer in the context of the Environment’s influence. It is precisely this interaction that sets the foundation for the mathematical analysis of the changes taking place and makes it possible to move from subjective assumptions to rigorous quantitative estimates.

From a mathematical point of view, a dynamic system is examined through a set of Planes — projections of data about the state of the system onto various dimensions. Each Plane is a kind of slice of information, recording one of the aspects of the Object’s state at a certain moment in time or over a certain interval. The most important property of the set of Planes lies in the fact that none of them can be considered more important or more truthful than the others: any individual projection reflects only a part of the overall picture, and only the totality of such projections makes it possible to build a holistic understanding of the process.

This key proposition explains why classical methods of analysis often fail: most popular models attempt to describe what is happening through one or two indicators, which is equivalent to considering only one or two projections. Such an approach is fundamentally limited, since a system always develops in several dimensions at once. For example, in a financial market these may simultaneously be price, volume, volatility, and the rate of change of price, each of which requires its own separate projection.

The main task of mathematical analysis in this approach is to record the reference points on each of the chosen projections. Reference points are extrema (maxima or minima) that possess statistical significance, that is, they are confirmed by the necessary number of data points before and after the point of extremum. Such a procedure makes it possible to minimize the probability of recording false fluctuations or random noise, characteristic of any time series. For example, if an extremum is confirmed by at least 3 bars before and 3 after, the probability of a random coincidence is significantly reduced, which makes the sample a reliable basis for further analysis.

Formally, if we denote the sequence of price data as $X = \{x_1, x_2, \ldots, x_n\}$, then the extremum at the point x_k is considered confirmed if the following conditions hold:

$$\forall i \in [k-m,\, k-1] : x_i < x_k \quad \text{(for a maximum)}, \qquad \text{or} \quad x_i > x_k \quad \text{(for a minimum)}, \tag{1}$$

$$\forall j \in [k+1,\, k+m] : x_j < x_k \quad \text{(for a maximum)}, \qquad \text{or} \quad x_j > x_k \quad \text{(for a minimum)}, \tag{2}$$

where m is the number of bars that sets the minimum length of the confirming interval (for example, 3 or 7).

After recording the extrema on each projection, one should determine the mutual arrangement of these points. The spatial relationships between the reference points form the geometric structure of the dynamics, which is the main source of information for forecasting the future development of the system. Such a structure is built through lines connecting the extrema, and the angles between these lines, which makes it possible to quantitatively assess the strength and directionality of the movement, as well as the probability of a change in the current trend.

Another crucial feature of the method is the principle of fractal invariance: the geometric structure built on the extrema preserves its properties under a change in the scale of observation. In other words, if on a large time interval the construction of the model showed a certain configuration, then on a smaller interval one can see analogous structures in miniature. This property makes it possible to apply the method both to high-frequency data and to long-term trends, obtaining comparable results and forecasts.

Mathematically, fractal invariance is expressed in the fact that the constructed lines and their intersections are invariant to affine transformations of the time axis:

$$f(t) = at + b, \tag{3}$$

where a and b are the parameters of scaling and shift along the time axis, which do not change the mutual arrangement of the extrema on the price scale.

The analysis algorithm is based on the minimal necessary set of points: for most basic models, four extrema are sufficient, alternating consecutively in direction (for example, minimum–maximum–minimum–maximum for an uptrend, or the reverse for a downtrend). Such a construction minimizes the redundancy of the data, but preserves the ability to precisely model even complex movements owing to the strict recording of the key changes in direction.

From a statistical point of view, the use of extrema makes it possible to employ the method of moments: extrema are points with the maximum change of the first derivative of the series (the velocity), and therefore concentrating the analysis on them makes it possible to identify trends and corrections in the most effective way. Unlike methods based on moving averages or smoothed indicators, extremum analysis does not suffer from signal lag, since the recording of an extremum occurs near the key turning point of the tendency.

The key mathematical merit of the approach lies in the fact that the analysis is conducted not on the data themselves, but on the relationships between the extrema, which makes the method independent of the absolute levels of prices or of the values of the object of analysis. This property makes it possible to apply it in the most diverse fields: from the analysis of quotations on the currency market to the assessment of fluctuations in production indicators or social indicators.

Thus, the mathematical basis of the method rests on three principles:

1. Identification of confirmed extrema to record the key points of change.
2. Investigation of the mutual arrangement of the reference points through the construction of lines and the determination of their spatial characteristics.
3. Preservation of the fractal structure of the constructions under a change in the scale of observation, which ensures the universality of the method across any time intervals.

These principles create a rigorous foundation for the subsequent construction of models of the dynamics, which make it possible not only to describe past movement, but also to forecast the further development of events while taking into account the objective regularities of the process.

3 The Geometric Idea

When data about the state of a system are represented in the form of a time series, simple tracking of price levels or other indicators does not allow one to see the structure of what is happening. A true understanding of the dynamics arises only when the data begin to be regarded as part of a spatial process, where what matters is not only the magnitude of the change, but also the mutual arrangement of the key points — the extrema. It is precisely the geometry of these points that makes it possible to reveal hidden dependencies and to predict subsequent events with a high degree of reliability.

The main idea of the method is that the extrema form the skeleton of the movement. Geometric constructions — the lines and angles connecting the reference points — represent objective and unchanging elements that remain stable even under a sharp change of external conditions. Such an approach makes it possible not merely to register the fact of a trend or a reversal, but to determine in advance its potential and the probable direction of its development.

Mathematically, each line drawn through confirmed extrema sets a local axis of movement. For example, if on a time series of price one draws a line through the first and third reference points, it will represent a trend line, recording the main direction of the dynamics. Similarly, a line through the second and fourth reference points reflects the targets of the movement and can serve as an indicator of potential zones of halting or reversal. Their mutual arrangement — parallelism, intersection in the past or in the future — sets the basic classification of models, determining the probability of the continuation or change of the trend.

The key point is that the lines are built strictly through extrema confirmed by statistical rules, which excludes the fitting of charts to a desired result. This provides the ability to forecast the development of events on the basis of unchanging regularities, rather than on the basis of the analyst's subjective opinion. The lines do not depend on which scale or timeframe is chosen: if the constructions are performed correctly, then their mutual arrangement will remain the same both on a 5-minute chart and on a daily one. This property is known as the scale, or fractal, invariance of geometric constructions.

By way of illustration: if the constructed lines diverge into the future, this speaks of an expansion of the range of movement — such models indicate a growth of volatility and high chances of a breakout of levels. If, on the contrary, the lines converge in the future, this points to a compression of the range and the probability of a trend reversal or a prolonged consolidation. When the lines are practically parallel, one speaks of a state of dynamic equilibrium, in which the price moves within a narrow range without a clear dominance of one of the sides.

Special attention is paid to the angles that are formed by the trend line and the target line. The angle between them reflects the degree of imbalance in the system: the smaller it is, the more strongly the trend is expressed; the larger the angle, the higher the probability of an imminent correction or reversal. This is connected with the fact that an acute angle between the lines means a concentration of extrema over a small time and price segment, which testifies to a sharp and strong movement, but also to its imminent exhaustion.

From a mathematical point of view, if the lines are given as the equations of straight lines

$$L_1 : y = k_1 t + b_1, \qquad L_2 : y = k_2 t + b_2, \tag{4}$$

then the angle between them is computed through the slope coefficients by the formula:

$$\alpha = \arctan \frac{k_1 - k_2}{1 + k_1 k_2}. \tag{5}$$

This makes it possible not merely to visually assess the convergence or divergence of the lines, but to quantitatively measure the strength of the trend or the tension of the system's state. It is important that the computation of the angle is performed independently of the scale of the chart, which is precisely what ensures the universality of the method.

Another important part of the geometric idea is the principle of the invariance of models under a change of external conditions. For example, if in the course of the construction the reference points remain unchanged, while the price fluctuates around the target line, then the model continues to operate regardless of the depth of these fluctuations. Only a breakout or the formation of a new confirmed point leads to the cancellation or revision of the model. Such an approach excludes the false signals that often arise in classical indicators during noisy fluctuations.

It should be emphasized: the entire geometric idea is built on a fixed order of constructing the points. For example, in the basic models the sequence of extrema must be strictly alternating: minimum–maximum–minimum–maximum for an upward tendency, or maximum–minimum–maximum–minimum for a downward one. A violation of this sequence is not permitted, since it would lead to an incorrect determination of the direction and strength of the movement.

It is precisely owing to the combination of the strict order of construction and the mathematically precise construction of the lines that the method makes it possible to achieve a high objectivity of analysis. Unlike methods that interpret only the current position of the price relative to a moving average or other indicators, the geometric idea is based on the analysis of the entire preceding structure of the movement, which makes the forecast more reliable and better grounded.

And finally, another important merit lies in the fact that the constructed models can exist simultaneously on several time scales, forming a hierarchy of models of different levels. Junior models can be formed within senior ones, showing local corrections against the background of a global trend. This provides the ability to analyze the movement from several levels of depth at once, which is extremely important when working with dynamic systems, where each phase of development may contain its own structure.

Thus, the geometric idea consists not only in recording the extrema, but also in creating an objective spatial model that describes the logic of change in the system. This model makes it possible to understand what state the system is in at present, and to forecast its behavior with a high probability, relying not on guesswork but on rigorous and reproducible mathematical rules. It is precisely this that makes the approach a valuable instrument for the analysis of complex processes, capable of significantly increasing the accuracy of decisions in any field where dynamics and the timely understanding of turning points matter.

4 Principles of Reliability

One of the key problems of most methods for analyzing dynamic systems — from financial markets to complex engineering processes — is a high sensitivity to noise, false signals, and subjective estimates. In traditional approaches, an analyst may interpret the same data differently depending on their expectations or emotional state, which makes the results unstable and poorly reproducible. In contrast to this, geometric analysis based on extrema and constructions through reference points was designed from the outset with an emphasis on reliability, verifiability, and the rigor of the algorithms.

The first principle of reliability lies in the strict rules for confirming extrema. The use of statistical confirmation through a certain number of bars before and after the point records only those extrema that possess a high probability of being true. For most models, the rule of 3 or 7 bars is considered basic: for example, a minimum is considered confirmed only if its value is lower than the minima of at least three preceding and three following bars. This check makes it possible to filter out random fluctuations caused by market noise or by rare, uncharacteristic spikes of values that may mislead the analyst.

The second important principle is the invariance of the choice of reference points. From the moment of their confirmation, extrema are recorded as reference points, and no subsequent data can change their location in the model. This guarantees that the construction of models and the analysis of their structure will not change depending on new data, unless those data form a new sequence of extrema satisfying the rules of construction. Such an approach excludes the possibility of "fitting" the model to the analyst's wishes and makes the analysis reproducible at any moment in time, provided the data are identical.

The third principle of reliability is connected with the hierarchy of models: each model operates within the framework of its own time structure, and the formation of a new model does not cancel the previous one, unless the new one has formed on the same extrema and corresponds to the rules for a change of trend. This is especially important when working with multi-scale systems, where the trends and corrections of junior levels may exist within more global models. Such a multi-level structure makes it possible to see both local and global tendencies simultaneously, and, most importantly, not to confuse them with one another, which often becomes a cause of errors in classical analysis.

The fourth principle of reliability lies in the absolute objectivity of the calculations. All constructions are performed according to an algorithm in which every step is strictly defined: beginning from the rules for selecting extrema, through the construction of lines and the calculation of their angles, ending with the determination of forecast targets. In the method there are no stages where subjective interpretation is permitted: if the data coincide, the result of the analysis will always be the same, regardless of who performs it. This property makes the method an ideal basis for automated decision-making systems or for the analysis of large volumes of data.

The fifth principle is the use of a mathematically justified order of construction: the extrema must alternate in a strictly specified sequence (for example, minimum–maximum–minimum–maximum). A violation of this sequence leads to an incorrect formation of the model and immediately signals that the dynamics being analyzed do not correspond to the conditions for applying the basic models. This protects the analyst from false constructions and errors of interpretation, which is critically important in environments where a decision must be made quickly and with high accuracy.

The sixth principle of reliability is connected with fractal invariance: models built on the chosen extrema preserve their properties regardless of the scale of the data. This means that the analysis of a movement on a chart with a period of 5 minutes and on a chart with a period of 1 day will yield constructions and conclusions of the same type, if the dynamics preserve the same structure. Such a property is especially valuable for trading and for the analysis of processes with a different frequency of changes, since it makes it possible to use unified rules and algorithms at all levels of data without the need to adapt the model to each timeframe.

The seventh principle concerns clear criteria for the cancellation of a model. In the method, the conditions under which a formed model loses its relevance are strictly defined: for example, the formation of a new model on the same extrema, or the breakout of critical levels calculated according to the original model. This does away with ambiguous situations in which the analyst does not know whether the model is still operative or not, and reduces the risk of a misunderstanding of the current state of the system.

The eighth principle of reliability lies in the complete absence of dependence of the analysis on external factors, such as news, expert opinions, or events not directly reflected in the data about the price or the object. The method works exclusively on the basis of objectively recorded data, which makes it possible to exclude the influence of emotions or informational noise. This is especially important in conditions where rapid changes of the environment can create the illusion of a need to revise the forecast, whereas in reality the data remain within the bounds of the model.

Finally, the ninth principle of reliability is the universality of application: since the method relies exclusively on the mathematics and geometry of extrema, it is not tied to any single field of application. Geometric constructions with the same rules can be used both for the analysis of prices on financial markets and for the assessment of the dynamics of economic indicators, physical processes in engineering systems, or even biological data. This opens up wide possibilities for applying the same set of tools in the most diverse areas, without the need to develop new methods for each task.

Thus, the principles of reliability laid down at the foundation of the method make it not merely an instrument for a one-off forecast, but a full-fledged system for analyzing dynamics, capable of working reproducibly under any conditions and on any data. This makes it possible to apply it both in a manual mode for the analysis of individual cases and to integrate it into automatic systems of monitoring and control, where the cost of an error is high and a stable and objective result is required.

5 Why Does It Work?

The main reason for the high effectiveness of the approach based on the analysis of extrema and their geometric arrangement lies in its ability to objectively record the key changes in the dynamics of a system. Unlike most indicators, which process data through filtering, smoothing, or averaging, extremum analysis focuses precisely on the points where a change of direction or a significant acceleration/deceleration of the movement occurs — that is, on the real "events" within the data. This makes it possible to immediately single out the moments when the system begins to behave differently, and to assess in a timely manner the strength and duration of the new tendency.

Fundamentally, the method works because any dynamic system that develops on the physical plane is subject to the principle of the alternation of phases: acceleration and deceleration, rise and fall, trend and correction. These phases always manifest themselves through extrema. Even if the fluctuations of a price or an indicator seem chaotic, upon careful examination they follow a certain structure of the alternation of maxima and minima. The method uses precisely this universal regularity — by recording the alternation of extrema, it makes it possible to build the skeleton of the system's dynamics.

Another important point is the strict mathematical formalization of the rules for recording extrema. This makes the analysis resistant to short spikes of volatility or market noise and makes it possible to focus on truly significant changes. Owing to this, models built on extrema possess a high robustness and do not give false signals during insignificant fluctuations.

The next reason explaining the workability of the method is the analysis not of individual points, but of their mutual arrangement. For example, a trend line drawn through the first and third reference points is formed not on the basis of intuition or subjective expectations, but on the objective relationship of already-accomplished extrema. A target line through the second and fourth points sets a forecast frame for further movement. These lines form an intersection that indicates the key levels and time points where, with a high probability, events will occur

— for example, a reversal or an acceleration of the movement. Mathematically, such lines are expressed as straight lines with equations of the form

$$L : y = kt + b, \tag{6}$$

and their intersections or angles provide a quantitative basis for forecasts.

Why does the analysis of angles work? Because the angle between the trend line and the target line objectively reflects the strength and speed of the development of the movement. The sharper the angle, the faster and more powerful the current movement, but the more quickly it may exhaust its potential. A wide angle, on the contrary, indicates a slow and stable development of the trend. This property makes it possible to quantitatively assess the character of the movement without the use of complex indicators and without the need to fit the parameters of the analysis to each specific situation.

Of particular importance for the workability of the method is the principle of the hierarchy of models and their nesting. The dynamics of any system have a fractal character: on large time intervals, trends consist of smaller trends and corrections. A model built on a senior timeframe determines the global direction, whereas models on junior timeframes make it possible to refine the local points of entry and exit, the zones of risk, and the targets. At the same time, and this is especially important, the rules for constructing the models are the same at all scales, which guarantees the compatibility of the analysis of the global and local levels.

An important factor in the reliability of the forecast is that the model does not react to new data if they do not violate the structure of the confirmed extrema. This means that fluctuations within the range of the model do not lead to the cancellation of the forecast or to the need to rebuild the analysis, until a new sequence of extrema appears that corresponds to the rules for a change of trend. Such an approach protects against the "repainting" of models — a widespread problem of indicators that can radically change their signals after the appearance of each new bar, making the analysis unstable and unfit for use in real time.

Why does the method work on any timeframe? Because it is built on a fundamental geometric dependence that does not depend on the scale of time: the mutual arrangement of confirmed extrema remains unchanged under a change in the temporal resolution of the data. If a movement preserves its structure, then an analysis performed on 5-minute data will be identical to an analysis on 4-hour or daily charts. This property of fractal invariance makes the method a universal instrument for analyzing any dynamic system, regardless of the frequency of the changes taking place.

Another reason for the high accuracy of the forecast is the objective mechanics of the cancellation of a model. In the method it is clearly defined: if a new model is formed on the same extrema, or if the price breaks through the key levels calculated on the basis of the original model, then the previous model automatically ceases to operate. This excludes ambiguous situations and relieves the analyst of the need to guess whether a forecast made earlier is still relevant.

In addition, the effectiveness of the method is conditioned by the absence of dependence on subjective factors, such as news, rumors, or the emotional state of the trader. The model takes into account only objective data, presented in the form of extrema and their mutual arrangement, which excludes the influence of human emotions and cognitive distortions on the result of the analysis. This is especially important in environments where a high speed of decision-making and the objectivity of the analysis are critically important.

Finally, the method works because any dynamic system, striving for stability or transitioning into a new state, leaves "traces" in the data in the form of regularities of the extrema and their spatial relationships. Geometric analysis records these traces and makes it possible to build forecasts based on the objective features of a change in the structure of the system. Such an approach ensures an accuracy and reliability of the analysis unavailable to most methods that rely on smoothed data or on the subjective interpretation of signals.

Thus, the method of analysis through extrema and their geometric constructions works because it is built on the fundamental properties of dynamic systems: the alternation of phases, the objective recording of key points, and the preservation of mutual geometric relationships that remain invariant under a change in the scale of time. These properties make the method a powerful instrument for the analysis and forecast of complex processes in any field.

6 Conclusion

The method of analyzing dynamic systems through the recording of extrema and the construction of models on their basis represents a unique approach, combining mathematical rigor, simplicity of application, and exceptional flexibility. Unlike most classical methods, which are based on the averaging of data, on smoothing, or on the subjective interpretation of charts, this approach makes it possible to build forecasts exclusively on the objective information obtained from the structure of the data themselves. This makes it a reliable instrument both for manual and for automated analysis.

The main advantage of the method is the ability to precisely record the key moments of a change in the direction of the system's movement, which is critically important when working under conditions of high volatility or rapidly changing tendencies. Owing to the strict rules for selecting reference points and constructing models, the results of the analysis remain reproducible and do not depend on human emotions or expectations. This quality is especially important for professional application, when the cost of an error can be very high.

In addition, the method is universal: it can be used for the analysis of time series of any nature — from the quotations of financial instruments and macroeconomic indicators to the data of production processes and even biological or social systems. The geometric analysis of extrema is applicable at any scale of time and preserves its structure under a change of timeframes, which opens up possibilities for multi-scale analysis and for integration with other methods.

Another important outcome of applying the method is the transparency of the results: each forecast can be justified by showing the constructed lines, angles, and the mutual arrangement of the extrema, which makes it possible to understand precisely what the analysis is based on. This property makes the method convenient not only for personal application, but also for teamwork, for the preparation of reporting, or for the defense of analytical conclusions before clients or colleagues.

In the end, the method of analysis through extrema and their geometric arrangement provides the ability to substantially increase the quality of decisions in any field where it is critical to determine and assess changes of tendencies in a timely manner. It makes it possible to move from intuitive and subjective analysis to a strictly formalized approach, which ensures stability, objectivity, and a high accuracy of forecasts — and it is precisely this that makes it a valuable instrument for everyone who strives for a professional and systematic understanding of the dynamics of processes.