# Structures of CRM Systems*

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## Abstract

The issue of examining CRM-system structures is becoming increasingly relevant amid the rapid development of information technologies and intense market competition. Modern enterprises striving for success require effective mechanisms for managing customer relationships, which in turn fuels growing interest in optimal CRM architectures. This study explores both basic and fractal approaches to organising CRM components, highlighting the use of mathematical tools—particularly fractal-dimension formulas that enable deeper analysis of internal and external interconnections within customer-data management systems. Employing visual instruments such as diagrams and tables clarifies key parameters and development trends of CRM solutions, while the principles of fractal analysis open avenues for expanding CRM architecture toward greater flexibility and adaptability. The paper concludes by outlining prospects for further investigation of fractal parameters in CRM systems with the aim of enhancing customer-base management efficiency and optimising business processes.

## Keywords

CRM systems, fractal analysis, business-process optimisation, customer-base management, fractal dimension

## 1. Introduction

The contemporary business landscape demands tools that simultaneously offer flexible data governance and deliver high-speed, high-accuracy information processing. CRM systems that meet these criteria are gaining traction in large corporations as well as in small and medium-sized enterprises. Traditional approaches to designing and operating CRM platforms, however, often overlook the intricate hierarchies that link customer data, partner information and internal workflows. As a result, adapting CRM architecture to rapidly shifting market conditions becomes problematic.

Specifically, the question arises of how the system's structure can be enhanced through models and equations that capture the multi-level interdependencies characteristic of modern information flows. This challenge is compounded by the need to formalise and visualise performance indicators while scaling the solution in both quantitative and qualitative terms.

Consequently, investigating CRM structures through fractal analysis is both timely and essential, as such a synthesis reveals consistent patterns and optimal modelling methods for complex customer-data management systems.

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## 2. Analysis of recent studies and publications

The challenges of designing and implementing CRM systems have been examined from multiple angles within information-technology theory and practice, including internal database construction, distributed customer-information processing and business-process integration within corporate platforms [1, 2, 4]. Research attention frequently centres on methods for enhancing customer interaction efficiency, optimising marketing activities and ensuring reliable storage of large data volumes [6, 11]. At the same time, academic work increasingly emphasises architectural flexibility particularly a system's capacity for scalability and adaptation under external and internal pressures. Against this background, fractal theory has emerged as a means of describing self-organising systems capable of reproducing their own structure at various levels [3, 5]. Several recent publications highlight mathematical models that help unify heterogeneous processes within CRM platforms, as well as the necessity of employing diagrams and tables to conveniently present large datasets on customer interactions [7, 8].

## 3. Purpose of the article

The aim of this study is to identify the principal structural patterns of CRM systems and to substantiate the use of fractal analysis in constructing a flexible, self-organising and scalable architecture. To achieve this goal, the work investigates the defining features of contemporary CRM platforms, analyses their relationship to fractal models and elucidates the mathematical expressions applicable to hierarchical solutions in customer-data management.

Special attention is devoted to both theoretical and applied aspects of forming fractal systems that can enhance customer interaction efficiency and streamline internal business processes. A further objective is to demonstrate the value of visual instruments, specifically diagrams and tables in facilitating the comprehension and analysis of the complex models underlying fractal-based CRM architectures.

## 4. Modelling methodology

The modelling methodology for a fractal CRM system combines structural analysis with iterative computations that emulate the self-organisation of subsystems across multiple scales. The first stage involves formalising the input data, which entails gathering information on customer profiles, communication channels and business processes that shape interactions between organisational units and the customer base [9, 10]. At this point, key parameters required for deploying fractal logic are identified, including initial performance figures, projected load volumes and the system's branching strategy.

The second stage constructs a baseline structural model interpretable as the 'parent' configuration. This model delineates the core CRM blocks, such as the analytics module, the marketing-management module, local customer-account servers and the contact-centre hub. Employing a fractal approach means that each of these blocks can undergo iterative subdivision, whereby every 'child' element inherits the parent's essential functions yet retains the ability to adapt to local specificities regional, product-level or functional [12]. To determine the depth of fractal nesting and the optimal ratio between subsystem count and data workload, the mathematical apparatus of fractal dimension is applied. Typically, the model analyses the relationship between the number of iterative blocks and the scale factor, assessing whether an increase in sub-blocks enhances throughput and capacity or instead overloads communication channels [13, 14].

The final stage entails repeatedly simulating scenarios at varying scales and recording key performance metrics. Here, correlation analysis particularly the Grassberger-Procaccia method is employed to reveal the density and intensity of links within the fractally organised system. If the system maintains a high degree of self-organisation and exhibits rising throughput or resilience with additional iterative subsystems, the chosen configuration is deemed near-optimal [15]. Should 'overload' or efficiency decline emerge, the model is refined by adjusting inter-block topology, recalibrating the scale factor or limiting the depth of fractal iterations. This iterative methodology delivers a balanced architectural design for the fractal CRM system and provides a reliable assessment of its behaviour under diverse load scenarios in real-world business environments.

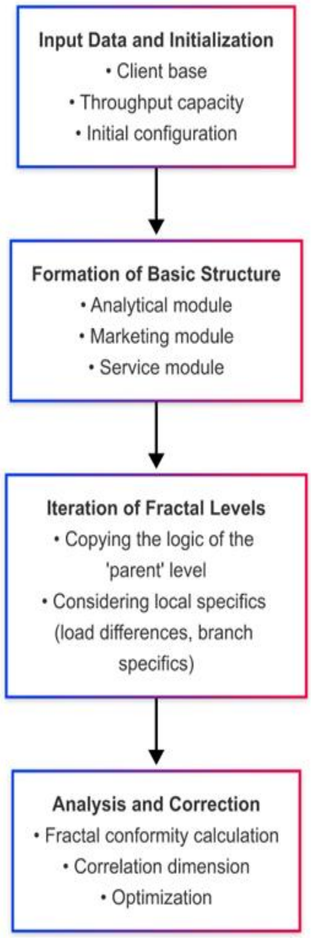


Figure 1: Methodology for modelling a fractal CRM system.

## 4.1. Presentation of the core findings

The development of CRM systems is closely tied to the need for rapid responses to customer requests and to the dynamic changes of the market environment [16, 17]. Classical systems usually distinguish several logical blocks that handle the collection, systematisation and analysis of customer-related data. Despite the practical advantages of such an approach, it often proves overly rigid, because it does not always take into account the complex links among different data entities. By contrast, the fractal paradigm assumes that every system block contains a certain structural similarity to the others, so automatic adaptation becomes possible through the "self-copying" of functional nodes at various hierarchical levels [18, 19].

Within CRM systems a fractal structure can be expressed through iterative procedures that build sub-modules, each of which reproduces the operating logic of the main module on a smaller scale while reflecting specific local parameters. To justify this idea, one should turn to the mathematical apparatus of fractals. One of the key indicators of fractal structures is their fractal dimension. In general terms it can be described by a formula that relates the number of elements to the scale of the object under study. For example, if $N$ is the number of sub-blocks and $r$ is the scale factor (that is, the ratio of a sub-block's size to the size of the original block), then the fractal dimension $D$ is defined as a ratio of logarithms:

$$D = \frac{log(N)}{log\left(\frac{1}{r}\right)} = -\frac{log(N)}{log(r)}, \quad (1)$$

In the context of CRM systems, this implies that by decomposing the overall customer-data-management platform into smaller subsystems each mirroring the parent logic—one can retain a "micro-image" of the entire complex at every level.

The need for a fractal approach also arises because large-scale CRM solutions, when processing substantial information volumes concurrently, begin to exhibit the intricate behaviour typical of self-organising structures [20]. Within such systems information flows not only vertically (from higher to lower tiers) but also horizontally, as data are exchanged among sub-modules or departments interactions that a traditional hierarchical methodology struggles to formalise in advance. Fractal geometry, however, enables the modelling of emergent links and the evaluation of their prospective effectiveness.

To illustrate the potential of fractal interpretation in CRM platforms, it is instructive to visualise a comparative analysis of system components across multiple scales. In this vein one may present aggregated data on how the number of service nodes N that handle a particular customer category changes with the scale factor r, spanning gradations from a local sales office to regional and global tiers.

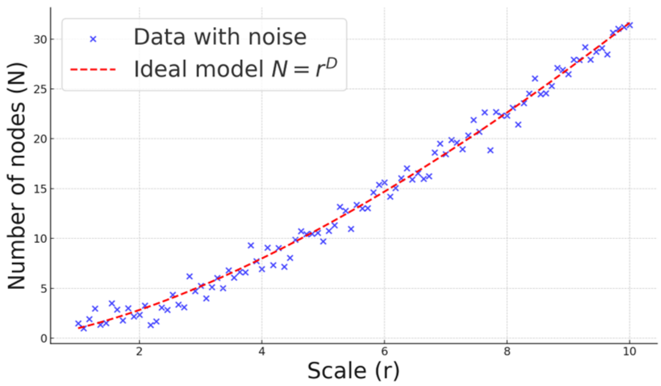


Figure 2: Graphical representation of the dependence of node count in a CRM system on the scale factor.

Fractal models further posit that when the number of system elements N increases geometrically, the interrelations among those elements may acquire new attributes of stability. Assuming that the self-organisation efficiency *E* in fractal CRM systems follows the same law as the quantitative characteristics of a fractal structure, an auxiliary equation linking *E* to the fractal dimension *D* can be expressed as

$$E = \alpha \cdot N^{D-1} = \alpha \cdot exp\big((D-1)ln(N)\big) \quad (2)$$

where $\alpha$ is an empirical coefficient that reflects the specific characteristics of the business processes involved, and *D* is the fractal dimension. This expression captures the tendency for efficiency to rise as the system scales provided the fractal nature of its interactions is preserved.

When building CRM systems it is also important to take into account how resources particularly computing power and memory are allocated across architectural levels. The degree to which a current configuration aligns with the fractal principle can be assessed through the fractal conformity index *F*, calculated from the performance coefficients of each level:

$$F = \frac{(P_1 \cdot P_2 \cdot \ldots \cdot P_k)^{\frac{1}{k}}}{P_\Sigma} \quad (3)$$

Here $P_1$, $P_2$, . . . ,$P_k$ denote the performance values of the individual subsystems, while $P_\Sigma$ is the total system performance. The closer $F$ is to one, the more the CRM platform exhibits fractal coherence across its hierarchy.

The essence of this formula is that the numerator computes the geometric mean of the performance values for every subsystem [20, 21]. This metric weighs each subsystem equally, unlike the arithmetic mean, which can be distorted when one or two units report abnormally high or low values.

Division by $P_\Sigma$ then shows how this geometric mean compares with the overall, system-wide performance. When $F$ approaches one, the subsystems are well balanced, and the CRM architecture displays strong fractal coherence: no critical gaps or bottlenecks appear, and self-similarity is preserved at every tier. If $F$ diverges significantly from one, it suggests that some modules differ markedly from the rest, breaking fractal harmony and potentially harming scalability and self-organisation [21, 22].

Because real-world business models are multi-faceted, a fractal approach to CRM design must consider hybrid configurations that combine corporate, regional and local subsystems [23, 24]. A tabular layout can present the performance values of these units along with their respective fractal-conformity index levels:

Table 1
Performance metrics and $F$-index calculation

| Subsystem | Performance $P_i$ | Characteristics |
|---|---|---|
| Module A (regional) | 0.80 | CPU: 2 cores, RAM: 4 GB |
| Module B (local) | 0.90 | CPU: 4 cores, RAM: 8 GB |
| Module C(cloud-based) | 0.90 | CPU: 4 cores, RAM: 16 GB |
| Geometrics Mean | $(0.80 \cdot 0.90 \cdot 0.85)^{\frac{1}{3}} = 0.85(approx.)$ | |
| $P_\Sigma$ (aggregated) | 0.88 (conditional integrated productivity) | |
| $F$ | $\frac{0.85}{0.88} = 0.97$ | |

Factors such as customer-request processing speed, the degree of integration with other corporate systems and the level of marketing-function automation must also be considered. Examining the resulting data in tables and charts can reveal new regularities in the distribution of resources and information flows.

A fractal structure decentralises and standardises processing logic, preventing overload on central modules and increasing overall system resilience. The same principle appears in complex-systems theory, where self-organisation is crucial for survival in a rapidly changing environment. This is particularly important for CRM platforms that need to integrate data from numerous communication channels: telephony, e-mail, social networks and feedback forms.

To verify the advantages of fractal organisation, one can apply the notion of correlation dimension, which measures the density of connections within the system. Let *C*(*r*) be the correlation function representing the number of element pairs that interact within a distance *r*. The correlation dimension $D_c$ is then defined as

$$D_c = \lim_{r \to 0} \left( \frac{log(C(r))}{log(r)} \right)$$

where

$$C(r) = \frac{2}{N(N-1)} \sum_{1 \le i < j \le N} \Theta\left(r - ||x_i - x_j||\right) \quad (4)$$

When a system possesses a pronounced fractal nature, the resulting value of $D_c$ differs from the topological dimension. In CRM platforms such analysis reveals how harmoniously the system's blocks integrate with each other and with external components. As the number of elements and communication channels grows, $D_c$ can increase, indicating heightened complexity and a more self-organised character.

The practical adoption of fractal CRM architectures has become feasible thanks to advances in computational infrastructure and the broader shift toward flexible cloud solutions. Within a cloud environment it is straightforward to scale according to the fractal principle, since additional mini-instances of CRM functions that reproduce the main system logic can be deployed on demand, providing stability and ease of maintenance. In many cases a hybrid fractal model is advisable, with certain modules remaining on a local server for security or performance reasons and others operating in the cloud while data coherence is maintained at the architectural level. All of these aspects should be visualised, for example through diagrams that relate performance to system complexity, thereby demonstrating convincingly that fractal design can balance reliability, speed and adaptability.

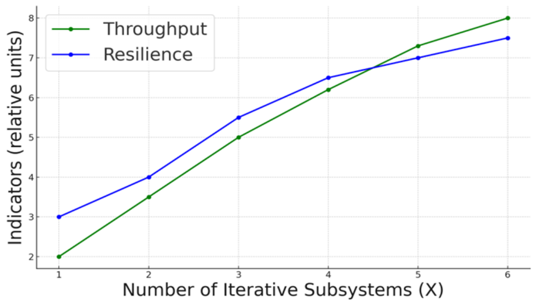


Figure 3: Dependence of CRM system throughput and resilience on the number of iterative subsystems.

The development of specialised analytical tools that merge machine-learning techniques with fractal analysis represents a promising direction for further research. For instance, customer-clustering algorithms can be enhanced by incorporating fractal characteristics of consumer behaviour data, enabling more accurate forecasts of potential market scenarios and more effective management of marketing campaigns.

## 5. Illustrative use case: fractal CRM in a multi-branch retail company

To demonstrate how the proposed fractal methodology can be applied in practice, we consider the case of a retail enterprise operating across multiple geographic levels: local stores, regional hubs, and a national headquarters. Each organisational tier interacts with its own customer base, processes transactions, and contributes to central analytics, while maintaining relative autonomy. Using the fractal approach, core CRM logic such as customer segmentation, marketing response tracking, and service workflow execution is replicated in lightweight modular instances deployed across all operational levels. These modules preserve essential architectural logic while adjusting to local parameters, including customer density, regional preferences, and staffing.

The company implemented this architecture using six layers of structural depth, each measured for performance and fractal conformity. Quantitative assessment was carried out using the previously defined formulas, including the fractal dimension $D$, the self-organisation efficiency index E, and the conformity index F. Subsystems with the highest $F$-index values exhibited superior balance between data throughput and processing latency, while those with weaker coherence showed signs of bottleneck accumulation. As communication channels diversified email, in-store interactions, app feedback—the correlation dimension $D_c$ increased, reflecting a rise in self-organising complexity and validating the predictive value of fractal metrics.

These results suggest that fractal modelling not only supports technical scalability but also aligns with the operational logic of distributed retail environments. By embedding adaptability and coherence into each architectural level, the system becomes more resilient to surges in customer activity and better equipped for strategic realignment. The use case affirms that the fractal paradigm is not merely a theoretical construct, but a functional design model applicable to diverse CRM ecosystems.

## 6. Conclusions and future work

This study has demonstrated that fractal analysis offers a viable framework for designing CRM system architectures that are both scalable and self-organising. By introducing mathematical constructs such as fractal dimension, conformity index, and correlation dimension, the work provides formal instruments for quantifying system efficiency and coherence across architectural levels. These tools not only support theoretical understanding but also offer actionable insights for developers aiming to balance load distribution and preserve functional symmetry.

The modelling methodology described herein emphasises iterative decomposition and recursive self-similarity, resulting in CRM structures that mirror macro-level logic within micro-level modules. This approach enhances modular flexibility and facilitates horizontal as well as vertical data integration capabilities that are critical for CRM platforms handling complex, multi-channel customer interactions.

Our findings indicate that geometric progression in subsystem replication correlates with improved performance metrics, provided that fractal balance is maintained. The use of the $F$-index to assess subsystem alignment has proven particularly effective, as it mitigates skew from outlier values and reveals latent inefficiencies in system design. The application of correlation dimension further enriches this analysis by measuring connection density and self-organising potential in dynamic environments.

Given the increasing shift toward cloud-native and hybrid IT ecosystems, the proposed model is readily adaptable to real-world infrastructures. Fractal scalability permits the rapid deployment of modular CRM instances across distributed networks, ensuring both resilience and continuity of service. In hybrid scenarios, where part of the system remains on-premises, maintaining fractal coherence becomes a strategic advantage for preserving data consistency and operational fluidity.

For future work, we propose the development of analytical toolkits that integrate fractal metrics with machine-learning methods. Enhancing customer segmentation algorithms with fractal feature sets may yield more accurate predictive models, thereby improving campaign targeting and lifecycle management. Additionally, simulation environments could be employed to refine dynamic fractal parameters under variable load conditions and network topologies.

In conclusion, this paper sets forth a theoretical and methodological foundation for a new generation of CRM systems those capable of adapting, scaling, and self-optimising within the fractal complexity of modern digital ecosystems. The fusion of mathematical formality with architectural pragmatism offers a promising direction for both academic inquiry and practical deployment.

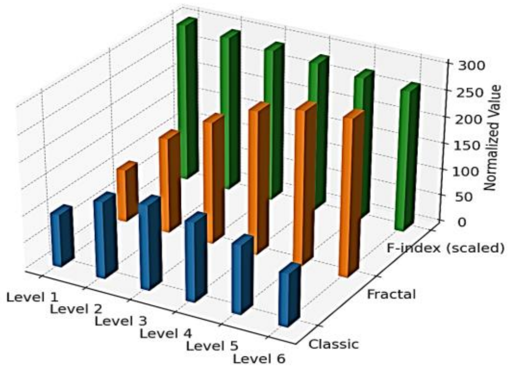


Figure 4: Comparative Diagram of CRM Performance and Fractal Coherence.

## 7. Limitations and numerical validation of the fractal CRM model

Although fractal analysis has proved effective for modelling CRM architectures, its applicability is bounded by several contextual constraints. The first limitation concerns heterogeneity: subsidiaries operating under divergent legal requirements or customer profiles may fail to inherit a self-similar structure without functional loss. The second limitation lies in data quality; metrics such as the fractal dimension *D* or the conformity index *F* rely on synchronised and noise-free logs. Inconsistent sampling frequencies or missing values distort geometric aggregates and disguise latent bottlenecks. A third constraint is resource overhead: excessive recursion depth multiplies communication links and can erode the very efficiency that fractal design seeks to secure. Where ultra-low-latency processes dominate, a hybrid arrangement—centralising critical paths while fractally scaling ancillary services, often proves more reliable than a uniformly recursive layout.

To ground these observations in quantitative evidence, consider a CRM deployment that consists of four autonomous functional subsystems: Sales Management, Customer Support, Analytics and Marketing Automation. Their peak-hour productivity figures, expressed in normalised throughput units, together with the aggregate system rate, are summarised below.

Table 2
Diagnostic Productivity Metrics and Fractal Conformity Validation

| Subsystem | Performance $P_i$ |
|---|---|
| Sales Management | 280 |
| Customer Support | 260 |
| Analytics | 300 |
| Marketing Automation | 260 |
| Total productivity P | 280 |

Applying the definition of fractal consistency, the geometric mean of the individual values is

$$G = (280 \cdot 260 \cdot 300 \cdot 260)^{\frac{1}{4}} \approx 274.49 \quad (5)$$

The resulting conformity index is

$$F = \frac{G}{P} = \frac{274.49}{280} \approx 280 \quad (6)$$

Because *F* is close to unity, the four subsystems perform in near-equilibrium, confirming that the recursive distribution of workload preserves fractal harmony. Should future monitoring reveal *F* drifting markedly below 0.9, architectural rebalancing either by reallocating compute resources or by reducing recursion depth would be advisable to forestall throughput degradation and maintain self-similar responsiveness across hierarchical layers.

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## Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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