Utilizing Geographic Information Systems for Power Networks

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ABSTRACT: : *GinisED is a geographic information system specifically designed for the needs of electric power utility companies Ginis ED was created by the CG&GIS lab of the Faculty of Electronic Engineering of the University of Niš and is used in ED JugoISTok Niš. One of the most essential features of GinisED is the tools for the spatial analysis of the electrical power supply network, the potential or actual events in the electric power supply network as well as the risk factors for a particular geographic area. To support effective spatial analysis, we have created a special data model to represent the electrical power supply network within GinisED. This data model is a mix of a topological model (where nodes and edges are used to represent geographic information) and a typical graph data structure for representing the attributes of the electric network.*

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1. Introduction

Making decisions based on geography is basic to human thinking because geographic location is an important attribute of all human activities policies, strategies and plans. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. Geographic information systems (*GIS*) are a special class of information systems that keep track not only of events, activities and things, but also of where these events, activities, and things happens or exist [1].

GIS enables capturing, storing, analyzing, and displaying geographically referenced information. It allows us to view, understand, query, interpret, and visualize data in a way that is quickly understood and easily shared. *GIS* technology can be used for scientific research, resource management, and development planning. Because geography location is very important for every day human activities, *GIS* solutions provide support for making decisions and solving many different problems: environmental monitoring, transportation management, public safety, facility security, disaster management, etc.

Management and visualization of underground utilities have been always of a great concern in many countries. Pipelines such as water supply, sewage, power supply, heat supply, industrial pipelines and communication lines, are essential infrastructures in cities. This tendency has been increased in the last decade while rebuilding and substituting existing principal pipelines to fit in with increased demands of citizens and industrial development. Moreover, newly designed underground pipelines for different purposes have been built along with various engineering projects. Insufficient, inaccurate and unclear information about the location and depth of cables and pipelines may cause various problems and may even result in tragic accidents [2].

Efficient functioning of utility companies engaged in the transmission and distribution of electricity cannot be achieved without proper record keeping and monitoring of the transmission and distribution network system [3]. Therefore, almost any electric power supply company has a need for the existence of specialized *GIS* solution that should provide mechanisms for collecting, storing and manipulating spatial data concerning transmission and distribution network system. This specialized GIS solution provides support for recording company assets, their locations their condition, how they are performing, and how much it costs to provide the service [4].

GIS tools for utility companies provide a very effective tool for generating maps and statistical reports from a database. However, *GIS* functionality far exceeds the purposes of mapping and generating reports. In addition to the basic functions related to automated cartography and data base management system, spatial analysis is the vital part of every *GIS* solution for utility companies. *GIS* is used to collect spatial data concerning distribution network, spatial analysis should be able to answer complex questions regarding space.

2. Related Work

The ability to take the geographic location of objects into account during search, retrieval, manipulation and analysis lies at the core of a *GIS*. How well these tasks can be accomplished is determined by the spatial data model. The starting point for modeling of geographic information is the geographic feature. A feature is an abstraction of a real world phenomenon. A geographic feature is a feature associated with a location relative to the Earth. A digital representation of the real world can be thought of as a set of features [5].

Among many of the commonly used *GIS* data models, simple features model has the most simple data structure. Every geographic feature has a unique persistent *ID*, set of thematic attributes (represented as alphanumeric data) and a number of geometric attributes. In this model, feature geometric attributes are limited to simple geometries. Simple geometries are defined as 2-dimensional geometries and linear interpolation is used for curve representation. Basic geometry types are points, lines and polygons [5].

Another model commonly used in *GIS* is the topological model [1]. Topological features are simple features structured using certain topological rules. Introduction of topological relations between features simplifies data validation, modeling behavior of connected objects and optimization of different spatial analysis. The network model is just a special case of the topological model. The network data structures are used for modeling flows. Tree structure is used to model the radial network, while the graph structure is used to model cyclic networks. As new elements, topological model introduces nodes and edges. A node is a distinguished point that connects one or several arcs. An edge is a line composed by a start and an end node. The advantage of this model is the topological information it is containing: every object includes information about the elements it is related to.

Database management systems are vital part of every modern operational *GIS* [1]. *DBMS* solutions provide *GIS* with standardized approaches for storing and, more importantly, accessing and manipulating geographic data using some standard query language. *GIS* provides the necessary tools to load, edit, query, analyze, and display geographic data. Innovative work in the *GIS* field has extended standard relational *DBMS* solutions with specialized support for storing and managing geographic data.

There have been several attempts to define a standard for representing and processing geographic data in relational databases. The *GIS* community, working under supervision of *ISO* and *OGC* boards, has defined the core geographic types and functions to be used in a relational *DBMS* and accessed using the *SQL* language [6].

GinisED is the geographic information system specially designed for electric power utility companies. It uses the most modern *GIS* technologies and methodologies for collecting. editing, visualization and analysis of spatial electric power supply network data. GinisED was developed by *CG&GIS* Lab, Faculty of Electronic Engineering. University of Niš, and is deployed in *ED* Jugoistok Niš (Serbian public electrie power supply company). GinisED helps *ED* Jugoistok Niš in everyday operation and maintenance as it provides the accurate, reliable spatial and non-spatial information to the utility operational staff, and in turn help them better meet customer needs [7][8].

GinisED (Figure 1) tools can be divided into three groups [4][5]:

• Tools for collecting (digitization, map scanning and vectorization using GPS and other specialized equipment) and editing the spatial electric power supply network data.

• Tools for visualization of spatial electric power supply network data for a certain geographic area.

• Tools for spatial analysis of electric power supply network, potential or actual events in electric power supply network and risk factors for a certain geographic area.

Basic components of the GinisED system are (Figure 1):

• ***Centralized geospatial database*** for storing data about electric power supply network. Elements of electric power supply networks are stored as a collection of geoobjects. Each geoobject is presented by its spatial component (coordinates or geometry) and thematic component (e.g. parameters for the conductors and protective devices such as voltage level, conductor type, length, construction and device type).

• ***GinisED Editor*** is a specialized tool for geographic editing of distribution network. It is a desktop application developed in accordance with carefully studied needs and requirements of customers. It is used for creation and editing of geographic schemes of the network, editing parameters of network elements and their connectivity.

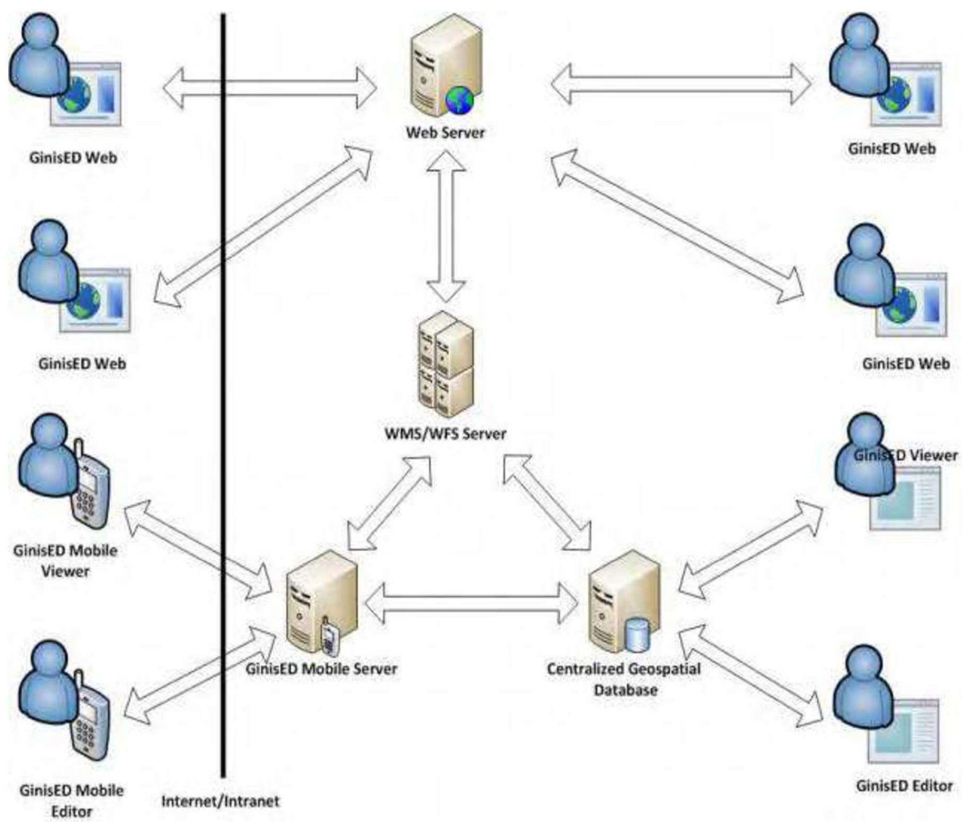

Figure 1. GinisED architecture

• ***GinisED Web*** is a Web *GIS* application that allows quick and easy positioning on a specific geographic area, search and selection of parts of electric power supply networks. This application implements information integration functionalities and uses data from centralized geospatial database.

• ***WMS*** [9], ***WFS*** [9] and custom Web Services are components that provide GinisED Web and GinisED Mobile Server with raster maps and information considering geo-objects. *WMS* and *WFS* are components built according to Open Geospatial Consortium specifications. Custom Web Services are used for data integration and enable GinisED Web with searching and reporting capabilities.

• ***GinisED Mobile Editor*** is tool for *GPS* survey of electrical consumers and relevant electrical assets. *GinisED Mobile Server* supports mobile *GIS* applications and provides map segments and synchronisation between mobile database and centralized geospatial database.

4. Model for Representing Power Distribution Network

In order to provide support for efficient spatial analysis we have developed a specific data model for representing electric power supply network in GinisED. Power distribution network usually contains features with line geometry (power cables of different types) or point geometry (substations, poles, street lights, etc.). The GinisED system provides 2*D* visualization of all the elements of the power distribution network (Figure 1). The major trace of power cables is mostly the same, i.e. under the streets, which results in overlapping lines. To avoid this overlap, in visualization we offset the multiple power cables to increase the readability of the map (schematic view).

In order to represent specifics of power distribution network we have designed GinisED network model (Figure 3). GinisED data model is a combination of topological network model (nodes and edges for representing geographic information) and typical graph data structure (for representing electric network attributes). The core part of GinisED network model is based on our GinisFrame object-oriented model for representing geographic features.

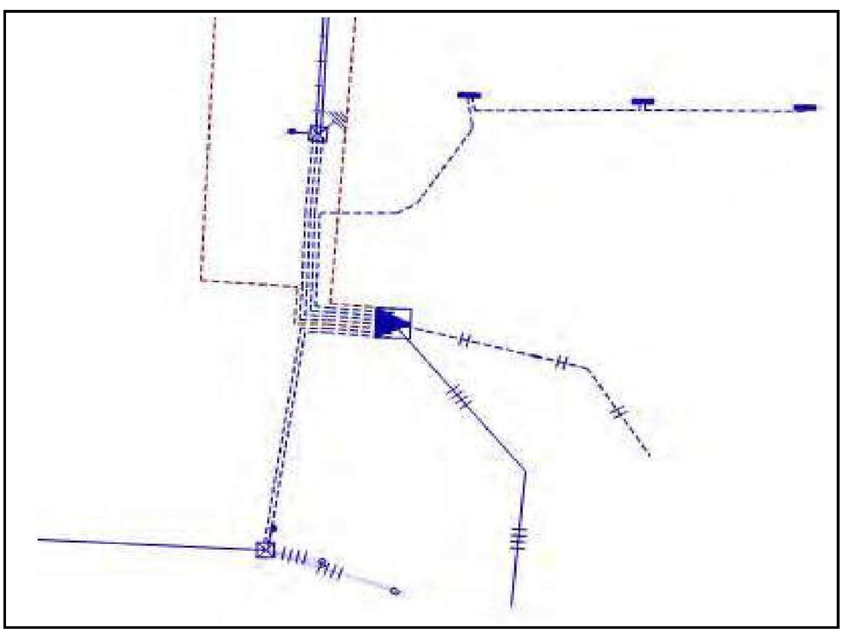

Figure 2. 2D visualization of power distribution network (schematic view)

Layer, FeatureLayer and Feature classes are derived from the original GinisFrame object model. These three classes define the basic organization of geographic information in GinisED system. Layer class is a basic organizational structure of our network model. Different layers can be organized in a hierarchical structure, thus providing a hierarchy and aggregation of geographic features. The FeatureLayer class defines layers of simple features (Feature class). This model is extended with NetworkObject class for network features and NetworkObjectLayer class for appropriate layers. Network objects, as opposed to simple features do not contain explicitly defined geometry. The geometry of the network features is indirectly contained in topological graph (Figure 3).

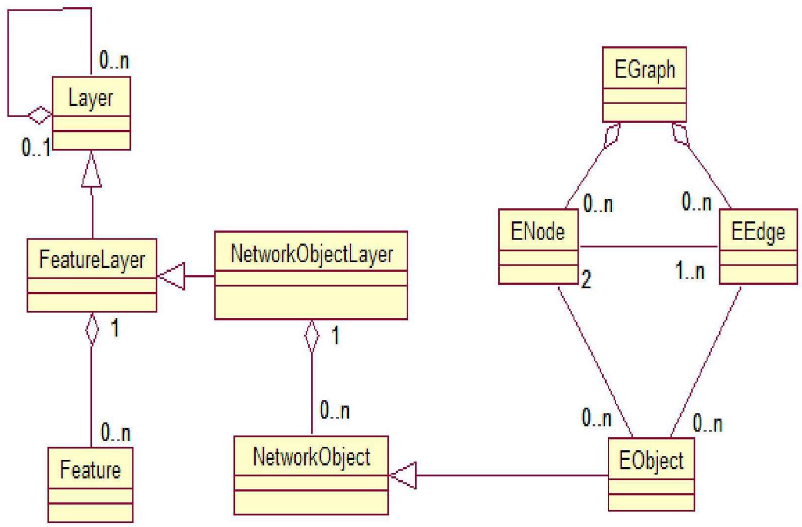

Figure 3. The GinisED network model

EGraph class implements topological graph that defines geometry of power network elements. EObject class implements power network elements and contains all thematic attributes. Geometry of power distribution network is defined through nodes (point geometry) and edges (line geometry). Additionally, every node element contains connection matrix that defines electrical connections between elements of power distribution network (Figure 4).

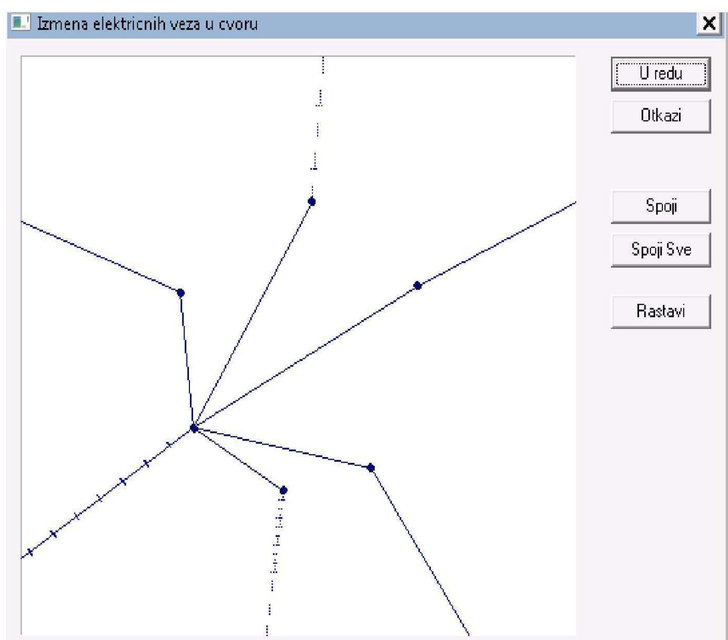

Figure 4. Electrical connections in node

GinisED system uses centralized geospatial database for storing data about electric power supply network. This database is implanted using Oracle *DBMS* (Figure 5). Each network feature on a map is stored as one logical record in *EOBJECT* table. A topological part of our model is stored in relational database using Oracle Spatial geometry model. Oracle Spatial geometry model has several simple geometry types and collections of them. One of the benefits of using Oracle spatial data types is that a quite extensive number of spatial queries can be performed at database level. In most scenarios spatial relationships of geometries such as "nearest to", or "within a specified region" are needed. Using this mechanism, queries which can be formulated as "is a cable at a particular distance from a cadastral parcel" or "find the nearest buildings and their distance to a specific cable or "find all underground networks in a given region" can be performed.

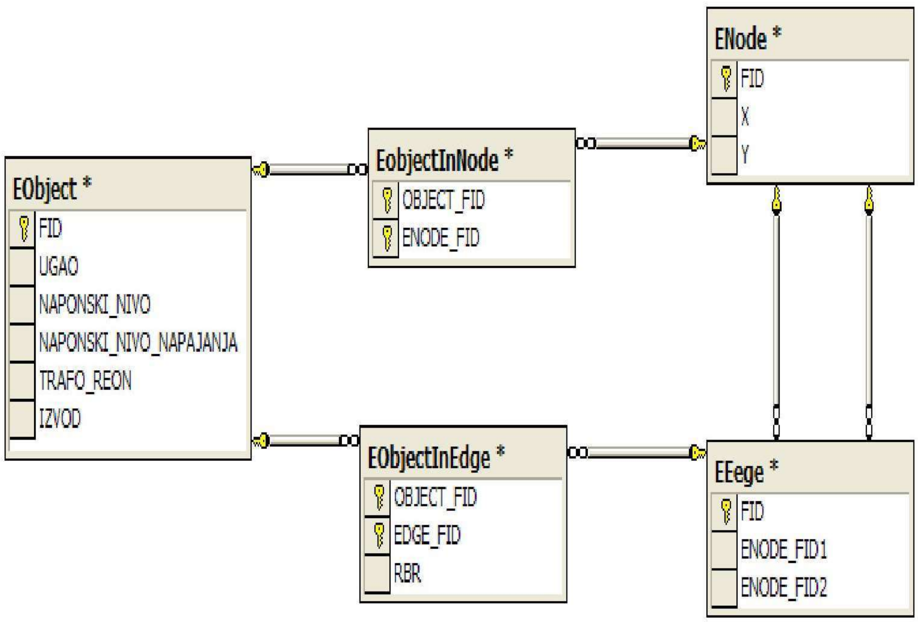

Figure 5. GinisED geospatial database

5. Ginised Tools for Spatial Analysis

Tools for spatial analysis are one of the most valuable parts of GinisED system. Creating making maps alone and generating standard statistics reports does not justify the high cost of building a *GIS*. The greatest strength of GinisED system is possibility to utilize various types of information in the spatial context and to generate new information and conclusions on the basis of this analysis.

A very important part of GinisED are tools for spatial analysis of electric power supply network, potential or actual events in electric power supply network and risk factors for a certain geographic area. Spatial analysis in GinisED involves two types of operations: attribute query (also known as nonspatial query) and spatial query. Attribute query requires the processing of attribute data without referencing spatial information. Spatial query involves selecting features based on location or spatial relationships, which requires processing of spatial information.

GinisED provides simple point-and-click query capabilities and sophisticated queries, analysis and display functions using visual, user-friendly techniques (Figure 6). GinisED provides timely information and decision making support to *GIS* users. It helps users to solve problems, analyze geographic situations, extract necessary data and generate new information.

While basic spatial analysis involves some attribute queries and spatial queries, complicated analysis typically require a series of *GIS* operations including multiple attribute and spatial queries, alteration of original data, and generation of new data sets. In order to support effective spatial analysis GinisED provide powerful query builder that can combine different types of attribute queries and spatial queries.

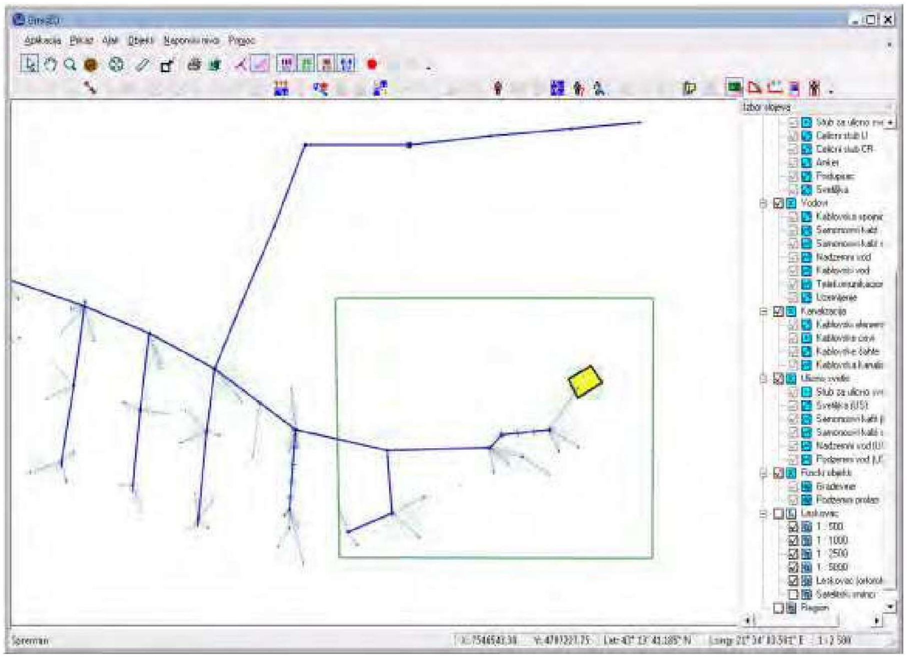

Figure 6. Spatial query: Find all network elements in specified region

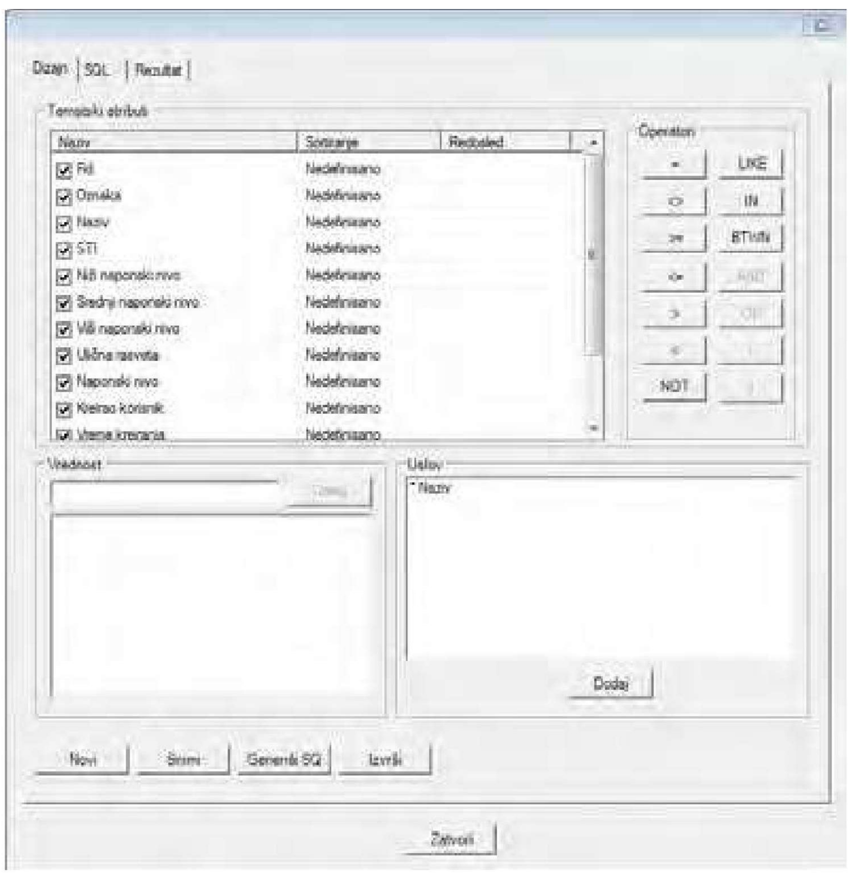

Figure 7. GinisED Query builder

6. Conclusion

Development of GinisED system for *ED* Jugoistok Niš has started in 2004. Before *GIS* was implemented, data maintenance was erratic and time-consuming. Keeping track of changes was difficult because hard-copy maps or digital *CAD* drawings were shared among the utility's different departments.

For the past six years implemented *GIS* solution has improved efficiency in overall company operations, GinisED quickly became an essential part of the *ED* Jugoistok Niš day- to-day business. Today, GinisED is considered very important data resource for the distribution analyses as it contains most facility information including major network topological structures. The circuit map display provided by the GinisED system is the most natural graphic user interface for engineers. In some applications, such as the trouble call analysis, geographic maps provide more information to engineers than the traditional one-line diagrams.

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