ORA: A Toolkit for Dynamic Network Analysis and Visualization

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Synonyms

ORA, ORA Toolkit, ORA-Lite, ORA-PRO, *ORA, ORA-NetScenes – note ORA is not an acronym

Glossary

Social Network Analysis: graphical, statistical and visualization metrics, algorithms and techniques for analysing structural data that can be represented as nodes and relations. Social network analysis is also referred to as network analysis, dynamic network analysis, network science, SNA, and DNA.

Social Media: data generated by an on-line social networking tools such as Twitter, Facebook or Foursquare. Social media networks are networks derived from social media data such as the Twitter retweet network. Social media are also referred to as on-line sources, open-source, e-media.

Dynamic Networks: networks that vary through time. An example is the network of who talks to whom within a company by day. Dynamic networks are also referred to as temporal networks, time variant networks, and dynamical networks.

Spatial Networks: networks embedded in space such that each node has one or more locations at which it occurs. An example is the network of who interacts with whom among political activists such that each activist is also linked to the locations at which they have taken part in

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demonstrations. Spatial networks are also referred to as geo-spatial networks, geo-intelligence networks, geographical networks, networks through space, and spatially embedded networks.

Meta-Networks: a network of networks, in which there are generally multiple classes of nodes, and multiple classes of link. Meta-networks are also referred to as high-dimensional networks, and geo-temporally embedded meta-networks.

Definition

ORA: A network analysis toolkit for graphical, statistical and visual analytics on both social networks and high dimensional networks that can vary by time and/or space. ORA is a full function network analytics package that supports the user in creating, importing, exporting, manipulating, editing, analysing, comparing, contrasting, and forecasting changes in one or more networks. ORA is a multi-platform network toolkit that can operate in stand-alone mode or as a service within a web architecture.

ORA ID card:

* tool name, title - ORA
* creation year - 1995
* author – Kathleen M. Carley
* scope – general
* copyright – academic student version, commercial full professional version
* type – program
* size limits – over 1 million nodes in batch
* platforms – PC, LINUX, and MAC
* programming language – Java GUI and C++ backend
* orientation – multi-disciplinary

Introduction

ORA is a network analytic and visualization tool developed by CMU and Netanomics, that allows the user to fuse, analyze, visualize, and forecast behavior given network data. Using ORA the user can reason about networks at the node, group, or network level. ORA includes a wide range of capabilities that supports multiple types of analyses; e.g., the user can analyze a social network using standard social network metrics; examine geo-temporal networks; identify key actors, key topics and hot spots of activity; identify communities, sub-groups and patterns of interest; examine changes in which nodes are key; examine changes in group membership, and so on. ORA is designed to support the analysis networks that vary in size (e.g. from small to large networks), type (e.g., the networks can be social, communication, semantic, task or other), and the networks can be high dimensional, aka meta-networks, that are dynamic and may be embedded in geographic regions.

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Key Points

There are several ways in which ORA differs from other social network toolkits. First, it actively supports high dimensional network data, often referred to as meta-network data, including changes in such data through time and embedded in space. Thus ORA has not just one-mode metrics, but two-mode, and multi-mode networks. It also has the ability to visualize social networks, two mode networks, dynamic networks, and can visualize networks on maps. Many of these metrics and algorithms are only available in ORA such as measures of cognitive demand, redundancy and the fuzzy grouping algorithm – FOG. Second, ORA supports analysis on very large network data sets. There is both a gui version of ORA and a batch mode version – the latter of which has been used with networks with 10^6 nodes. Third, ORA is interoperable with a large number of other tools. For example, data in csv, tsv, UCINET, or Twitter json formats and many other formats can be directly imported. Further, ORA can export to Google Earth, or to KML files, thus enabling interoperation with GIS tools. Fourth, ORA has been designed to reduce training time and effort on the part of the user through the automation of common workflows. For example, output is organized by topic which enables the user to select a topic and then all the major metrics used for that topic are automatically computed and printed to a web-page. This means that the user does not have to remember what metrics to run. As another example, common sequences that are done by users are automated and occur with a single keystroke. Fifth and finally, ORA has an integrated on-line help system, tool tips, QuickStart Guide (Carley, 2013), users-guide (Carley et al., 2017), and an associated Google-groups to provide help. Two text-books provide guidance in network analysis and show those analyses in ORA (Everton,2012; McCulloh et al., 2013).

Historical Background

ORA was originally developed as a network and visualization toolkit to support reasoning about changes in network within organizations from a meta-network perspective. This led to the organizational management report which not only identifies key actors but also assesses the level of shared situation awareness, individuals who might be over or underworked, and other factors that can lead to organizational problems such as the identification of insider threats. ORA has evolved enormously from this simple beginning.

ORA was extended to support link analysis in addition to social network analysis, for complex socio-cultural systems. This led to improved visualization, data entry, and multi-mode metrics. This also led to support for reasoning about the network in context, placing networks on maps, and visualizing the trails that led to the formation of network ties.

ORA was extended to support semantic network analysis and to enable the user to build networks from text. That led to the inclusion of new rhetorical based network metrics, and interoperation with text-mining software such as AutoMap and NetMapper. This was then extended to support hashtag network extraction and the ability to manage user thesauri.

ORA was extended to support network pattern of life analysis. This led to the inclusion of spectral analytics for networks and network change detection in addition, standard regression and Fourier analysis for network metrics thus supporting additional dynamic analytics.

ORA was recently extended with new special metrics for analyzing Twitter and Blog data, ego-network metrics, importers for BibTex and other citation formats, and new procedures for sorting big data to reduce what is imported.

Today, ORA supports full spectrum network analytics and visualization for small to very large networks. It has evolved into a widely used tool that is interoperable with many other technologies. It supports network analytics across a large number of domains, and has been used in a wide variety of theoretical and applied contexts, such as health care, pharmacology, building design, organizational team assessment, and social media assessment.

ORA

ORA is intended to be a comprehensive analytic and visualization engine for network analytics and forecasting that transcends traditional disciplinary boundaries as it supports standard social network analysis, link analysis, geo-network analysis, and dynamic network analysis. The algorithms in ORA are thus from a large number of fields (Carley & Pfeffer, 2012). In a similar vein, ORA supports data entry from and export to many other tools common in fields where network analysis is used. ORA supports analysis of many types of networks – e.g., social networks, social-media networks, communication networks, activity networks, population movement networks, netflow data for IPs, and semantic networks. As such, there are many metrics in ORA that are specialized to certain types of network data – e.g., geo-temporal networks. ORA is organized by the questions the user asks, not the metrics. As such, common workflows are automated and all metrics relevant to a particular question are automatically included in a report providing the network answer to the question of interest. Visual analytics are a key feature in ORA which employs both graphical, statistical and visual analytic algorithms to help the user assess, visualize and forecast behavior for social networks or high dimensional networks that can be dynamic or spatially situated. ORA supports 2D and 3D network visualization, geo-spatial network visualization for 2D and 3D maps, network dynamics, heat maps, loom or trail visualization, nodel (a node variant of wordl) and chart visualization capabilities. Finally, ORA supports reasoning about and with networks through the inclusion of basic matrix algebra and logic operations, algorithms for generating synthetic networks, search and selection procedures, and simple simulation engines and comparative statics for examining the potential impact of change. The basic interface to ORA and part of several reports are shown in Figure 1.

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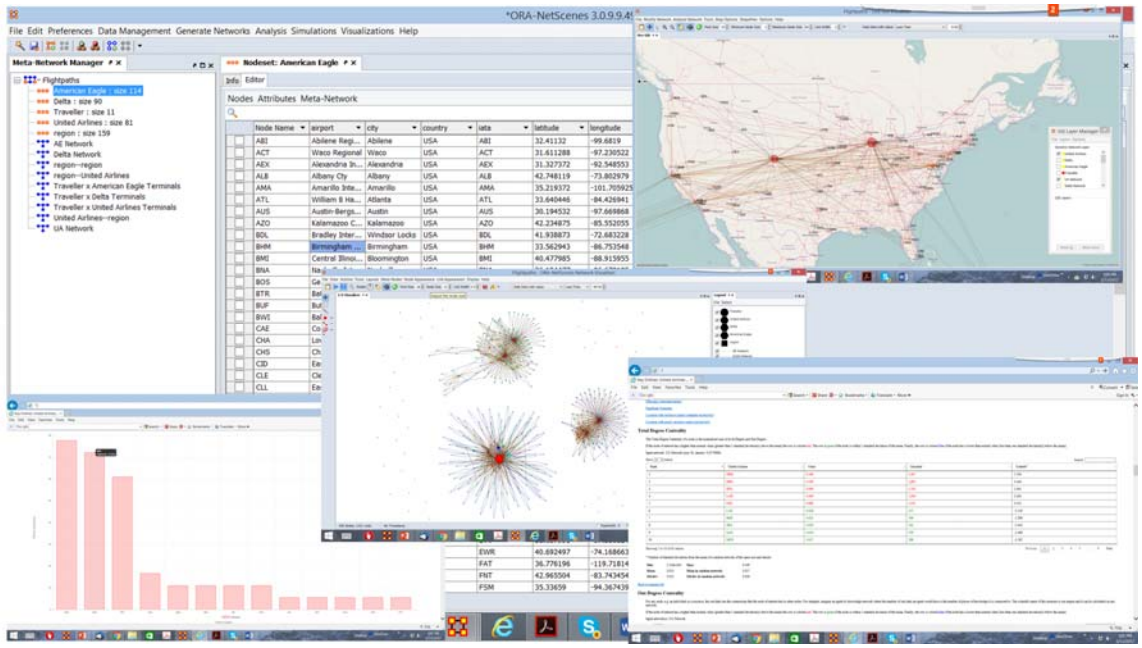

Figure 1. Illustration of ORA in operation.

What can be done in ORA?

Using ORA the analyst can identify key nodes using one-mode, two-mode, or multi-mode metrics. In ORA these can be segmented into agents, organizations, knowledge, resources, tasks, events, beliefs, and locations. In addition the analyst can use ORA to characterize, compare and visualize networks, conduct what-if assessments, identify groups using both community detection routines and specialized patterns, assess changes in the nodes, groups and networks, visualize and statistically analyze trends, identify patterns in the networks, examine the nodes, groups and networks in terms of where they are by using the geo-spatial mapping functions, and multiple other tasks. Both ego-network and full network can be analyzed. Temporal data can be analyzed and visualized as dynamic networks or as trails. Data can be sorted, cleaned, merged and sub-groups extracted. Within ORA there are wizards for many multi-step functions such as data importing, cleaning a visualization, and running common metrics. Many of these wizards lead the user through a set of decision when analyzing the data and generating reports. A list of the illustrative reports, functions and generators in ORA is in Table 1. The system is organized by questions that the user might ask of the data, and many common workflows are built in to reduce time to do standard analyses. For example, a typical network question is what are the key nodes? The Key Entity report automatically runs various centrality metrics and 2-mode networks for identifying key nodes. Which metrics are run depends on the entity type – i.e., whether the nodes is a who, what, where, why or how. Figure 1 shows parts of the Key Entity report.

ORA can also go beyond node analysis. For example, it contains a wide range of grouping, clustering, pattern and community detection algorithms. These are available in the Locate Group report. Moreover, within the visualizer the user can color nodes by the groups they are in. ORA also supports change detection and spectral analysis for network metrics at the node and graph level. Using these techniques dynamic data can be assessed and changes and regularities in the way network metrics and nods behave over time can be characterized.

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Table 1. ORA Analytic Capabilities

Reports	Reports	Network Generators
All Measures Belief Propagation Blog Report Capabilities Communications Network Assessment Communicative Power Communicators Context Core Network Critical Sets Detect Spatial Patterns Drill Down Geospatial Assessment Group Talk Content Analysis Immediate Impact Influence Net K-Centrality Key Entity Large Scale Local Patterns	Locate Groups Management Missing Links Network Distribution Optimizer Part Of Speech Potential Errors QAP/MRQAP Analysis Role View Semantic Network Shortest Path Simmelian Ties Analysis Sphere of Influence Standard Network Analysis Statistical Change Detection Statistical Distribution Topic Analysis Trails Trails Analysis Twitter Unique Trails Report	Stylized Erdos-Renyi Core Periphery Scale Free Cellular Lattice Small World Fixed Degree Distribution Calculated from Existing Data Expected Interaction Expertise Similarity Distinctiveness Resemblance Command and Control Infer beliefs Influence Network Matrix Algebra User Entered Network Through Editor Through Visualizer
Grouping Algorithms and Pattern Identifiers	**Visualizers**	**Functions**
Grouping: Girvan-Newman Louvain Components Concor Johnson Hierarchical K-Means K-Core Attribute-based K-Fog Spectral Alpha-Fog Local Patterns: Minimum Spanning Tree Cliques Hidden Links Stars Checkerboards Balls and Chains Cycles	Measure charts View measures over time View networks over time Network drill down Node cloud Color grid Network block 2D Geo-spatial networks 3D Geo-spatial networks Region viewer Trails Trails in GIS 2D network 3D network	Correspondence Analysis Geary C and Moran I Analysis QAP MrQAP Simulators Micro-Sims Information Diffusion Disease Propagation Goods Dispersion Near Term Analysis

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User Control and Awareness

There are an increasing number of people who want to analyze networks; however, many of them have had little training in network analytics. This can lead them to make errors in analysis without realizing it such as identifying a nodes centrality when the "network" contains multiple types of links and nodes. ORA tries to minimize this by providing more user guidance, not allowing functions that are known to not be applicable, and making the user be explicit about what node class a node is in and the nature of the relationship. Moreover, ORA makes explicit whether the results are based on the status of the underlying network such as whether it is binary or symmetrized. Studies show that ORA results map onto other common widely used network analysis tools when the user manipulates the data to match the way the other tool alters the data by default (Wei et al. 2011).

High End Visualization

ORA supports many types of visualization - see Figure 2. The visualizer and the data editor are linked so that a change in one effects a change in the other. Thus the user can directly enter or edit data in the visualizer, or the user can directly see the impact on the network image as nodes are merged or deleted in the editor. Standard graphing tools are used in reports for things such as pie charts, spider graphs, scatter plots and histograms.

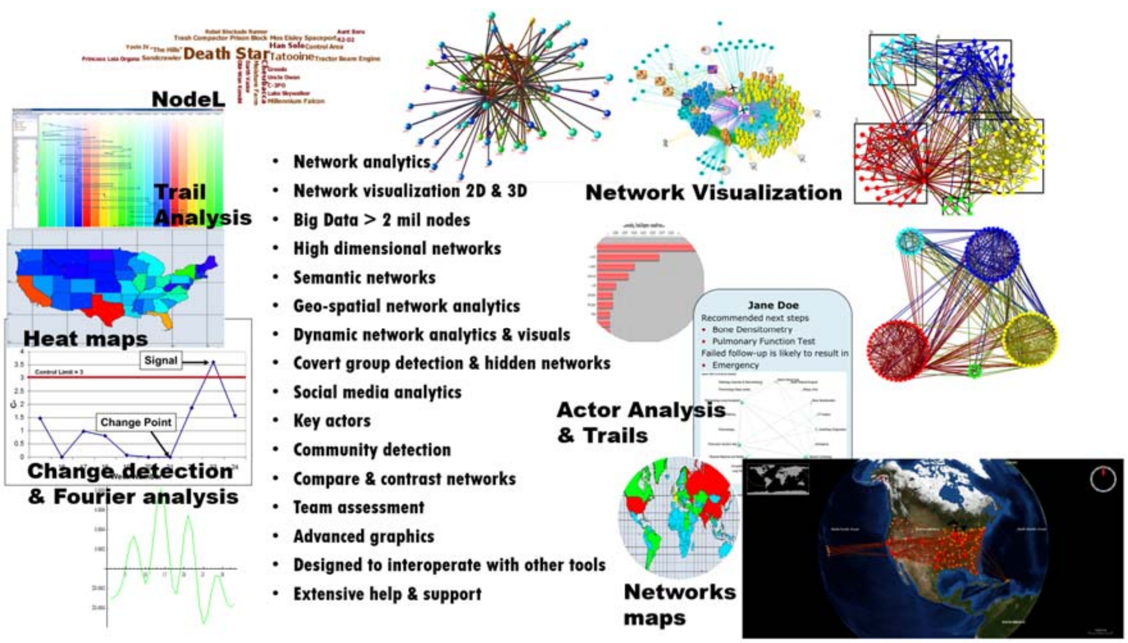

Figure 2. Illustrative Visualization Capabilities

Temporal Analysis and Geo-Temporal Analysis

ORA facilitates examining networks as they change through time, and the movement of networks through space. Most reports, if the user has two or more time periods, automatically does a comparison and with three or more networks provides trend information. In the visualizer the network over time feature allows the user to step through changes in the network in a movie like fashion, and view changes over time for measures or nodes of the user's choice.

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For multi-time period data spectral analysis and change detection are available (McCulloh et al., 2012). Spectral analysis supports the user in assessing the regularities and anomalies in temporal network data. Graph or node level metrics can be examined over time and the "patterns of life" identified, such as the drop in twitter activity at 4 am or an increase in the centrality of a team lead in email traffic immediately after a group meeting. Change detection is a forensic technique that supports the user in identifying when a change in a dynamic network occurred that led to the current signal. These are supplemented with full Fourier analysis capabilities.

There are two different techniques for what-if analysis that support reasoning about change. The first of these is the immediate impact report where the user can select a set of nodes or links to remove and then a static comparison is run between the original network and the hypothetical new network. The second technique is the near term impact report where ORA calls the network simulator Construct already instantiated with data from the network being analyzed. Then a simple simulation based virtual experiment is run.

Geo-temporal networks can be handled as trails. The trail format captures data of the form who/what was where when such as people moving through a building or authors publishing papers in different journal through time. ORA supports changing data from trails to networks and networks to trails. Moreover, it supports direct analysis of trails in the visualization sub-tool – LOOM. A special report, identifies the geo-temporal clusters using a trial clustering algorithm (Gullapalli and Carley, 2013).

Big Data Analytics

ORA is supports the analysis of networks varying in size through wizards and optimizations that change how the system operates depending on the data size. Approximation algorithms such as the k-centrality algorithms (Pfeffer and Carley, 2012) and special big-data metrics are included. Special features for big data include ability to turn off slow metrics such as betweenness, automated grouping prior to visualization, and data sub-selection on import. The professional version of ORA can be run either through the interface or from the command line. All metrics have been optimized for sparse matrices. New dense matrix techniques are being added. Tests have shown ORA capable of running, through command line or on very large multi-processor machines analytics on networks with 10^6 nodes and 10^7 links.

Interoperability

ORA is designed to work synergistically with other applications. To begin with there is the data to model workflow (Carley et al., 2007) designed so that the user could step through extracting networks from texts (AutoMap, Carley et al., 2013a), then analyze those networks (ORA, Carley et al., 2017), then simulate changes in those networks (Construct, Carley et al., 2012a; Carley et al., 2009b; Carley et al., 2012c). This interoperability is made possible through the use of DyNetML a variant of GraphML that support large scale dynamic network of high dimensional data. The format is completely open. Secondly ORA can import from and export to a number of formats. For example, data can be imported in a number of ways, including from Excel, CSV, TSV, UCINET, Pajek, Analyst Notebook, PenLink, Personal Brain, GraphML, shape files, and various twitter and blog JSON formats. Images can be saved in pdf, tiff, jpeg, svg, and a proprietary editable format. Shape files in KML can be exported from the geo-spatial visualizer which can also port to NASA WorldWind and Google Earth. Reports are in HTML and work with most browsers, CSV and often PDF formats are also available.

Key Applications

ORA has been used in a wide number of contexts. New applications appear frequently. Selected illustrative applications are listed in Table 2. In essence, the use of ORA is only limited by the user's imagination. The meta-network flexibility admits analysis of many kinds of data, from social networks of who interacts with whom, to Twitter networks, to studies of who is critical and what did they do where and when. Illustrative examples of how ORA has been used in various contexts include: assessment of covert activity (Carley et al., 2009a), citation analysis (Kas et al., 2012), social media analysis (Carley et al, 2013b), public health (Merrill et al., 2012), hospital safety outcomes (Effken at al., 2013), care coordination (Merrill et al., 2015), structure of ethnic violence (van Holt et al., 2012), the Arab Spring (Carley et al., 2015), terror groups (Kenney et al., 2012), and impact of Twitter suspensions on network statistics (Wei et al., 2016).

Table 2. Illustrative Uses of ORA

Organizations	Law & Military	Health	General	Text Analysis
Design Team Management Silo Identification Productivity Assessment Command Level Cyber Security Software Design Teams Organizational Email Citation Networks Interlocking Directorates	Counter-terrorism Counter-narcotics Human Trafficking Piracy Counter-IEDs Atmospherics Socio-cultural Geography Open-Source Analysis Covert group identification Global Hostility and Alliance Networks	Fall and Medication Errors Public Health Coordination Disaster Response Autism care networks Disease Spread Health Related Twitter Disaster Related SMS MD Referral Networks Journal Networks	Housing Design Bridge design Barrier Reef Protection Global Cyber Security Curriculum Evaluation P2P networks Cyber Attack Networks Cyber Netflows	Semantic Networks Topic Groups Hashtag Networks Changing definitions Communicative Reach Analysis Fake News Identity Assessment

Future Directions

ORA is evolving in several ways. These include supported platforms, data entry and manipulation, algorithms, big-data analytics, statistical reasoning, and interoperation.

Platforms: Currently there is both a free student version for the PC and a more comprehensive professional COTS system able to handle larger data faster and with better 3d and geo-spatial capabilities. Mac, and Linux versions exist as COTS. An enterprise version that supports scripting and a web-version for operation in Ozone are being extended.

Data Entry and Manipulation: New optimized workflows for parsing big-data from csv exist; variants for JSON are in development. The system would allow degree centrality, k-core, components and edge weight to be used to preselect parts of the network for analysis. The ability to make nodes and attributes interchangeable is also under development.

Algorithms: Currently there are over 150 metrics and 20 grouping algorithms in ORA. New incremental and approximation metrics, and new group level measures are being added to support big dense networks.

Big Data Analytics: ORA has been optimized for large-scale sparse matrices. The scripting version can handle 10^6 nodes. Metrics are ordered by their speed so the user can choose through the interface to run only fast measures, to run all but the slowest measures, or to run all measures. Currently, new metrics to support even faster processing are being implemented. These include the incremental metrics for closeness (Kas et al, 2013a) and betweenness (Kas et al, 2013b). ORA was recently refactored to support improved speed for handling multiple time periods at once and big data visualization.

Statistical Reasoning: ORA currently has a version of QAP and MRQAP. The MRQAP routine is being extended to allow the user to specify and run multiple models with a scripting approach. Further, an ERGM module for ORA is currently under development. Finally, most reports provide some guidance as to whether the metrics observed are within or beyond the bounds expected given a normal distribution; comparison against a second baseline – a scale free distribution are underway.

Interoperation: Wizards for increased interoperation with R and technologies that extract social media or do forecasting are currently being developed. APIS to support integration into workflow systems and to support user addition of metrics are planned.

Cross-References

[Related entries in the Encyclopedia of Social Network Analysis and Mining; please find the complete list of all contributions at http://oesys.springer.com by going to "download current List of contributions as a pdf document"

Please enter your list of cross references here:]

Analysis and Visualization of Dynamic Networks *Long Essay* 00382 6/6

Anonymization and Deanonymization of Social Network Data *Long Essay* 00022 8/8

Centrality Measures *Long Essay* 00227 15/15

Clandestine Behaviors and Social Networks, Analysis of *Long Essay* 00195 16/16

Classical Algorithms for Social Network Analysis: Future and Current Trends *Long Essay* 00026 17/17

Combining Link and Content for Community Detection *Long Essay* 00214 31/31

Community Detection in Social Network: An Experience with Directed Graph Ls*o ng Essay* 00049 36/36

Community Detection, Current and Future Research Trends *Long Essay* 00027 37/37

Community Identification in Dynamic and Complex Networks *Long Essay* 00380 40/40

Evolution of Social Networks *Long Essay* 00318 84/84

Inferring Social Ties *Long Essay* 00177 125/125

Large Networks, Analysis of *Long Essay* 00031 135/135

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