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Computational Framework for Web Metrics towards Automated Web Design

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Abstract: *The discipline of engineering of software has evolved from software engineering to web engineering, and now to cloud engineering, the last of which develops required resources & environment for cloud computing. Apart from the technical characteristics of each, software engineering has been first product-oriented and then also process-oriented; web engineering has client-orientation and now cloud engineering is oriented toward open-endedness. Because of changes in the orientations and other concerns during the evolution, from time to time, the sets of web metrics required have also ever been evolving. Thus, any approach/ framework for (knowledge-base of) metrics must be flexible. The proposed framework is flexible enough to incorporate changes with minimum efforts. The framework assumes LISP-like environment and assumes single abstract data type (ADT), viz. list (or recursive list). The ADT is not only a data type, but basic program construct also, with the advantage that even programs may be treated as data and can be given as inputs to any program including itself.*

Keywords: *web design automation, web metrics flexible knowledge-base, web facets: science, social science, engineering etc.*

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I. Introduction

Relevant metrics play significant role in proper design & development of desired products in any field of engineering including that of web engineering. Also, metrics are required and used to evaluate appropriateness and efficacy of a product, after its launching, through feedback from the relevant sources, including the users of the product. However, in the case of World Wide Web (or, Web, or even web)—for its engineering and usage—the number of metrics, and even of their types, is quite enormous. Without appropriate framework, it is practically impossible to find a metric appropriate for a particular purpose during the process of engineering or usage. In this regard, a framework is purposed. The approach for the proposed framework is not merely theoretical and usable only by human experts, but, can be automated.

Automating an engineering task is quite complex because, first of all, it involves two types of contrasting intelligences: (i) Human intelligence which is rooted in informal expression, judgmental evaluation, inductive reasoning and commonsense, and (ii) The machine intelligence which is essentially based on formal expression, formal rule-based evaluation & deductive reasoning etc. Human intelligence is required for understanding the problem domains & their environments, and then using the understanding for designing & developing solutions in such a form that it is understood and executed by the contrasting intelligence, viz. the machine intelligence. Further, for automating of an engineering task, not only the relevant data structures and programs are expressed in a formal programming language, but even the control—by which, among other matters, the sequencing of execution of various programs etc. is done—has to be expressed in a formal, machine-readable & machine-executable form in some programming language.

An approach has been proposed in [1] for automating web design, which takes care of the above-mentioned facts and concerns. For this purpose, solutions—conceived by human experts—are generally expressed in some natural language and are, first of all, translated to semi-formal mathematical entities: recursive lists. An element of a recursive list may be text, an icon, a hyperlink, a function/procedure call, or even a list of such elements. These recursive lists are then easily translated to fully formal entities in some functional programming language like LISP or Haskell.

In context of software, flexibility of an approach/framework is essentially required in view of the fact that the discipline of engineering of software has evolved from software engineering to web engineering, and now cloud engineering, the last of which develops required resources & environment for cloud computing.

Web Applications characteristically differ from the conventional ones, at least in the matter of Web hypermedia applications characterized by the authoring of information using nodes, links, anchors, access structures for navigation, and delivery over the Web. And, Web development differs from software development regarding a number of issues including: the people involved in development, the intrinsic characteristics of Web, and the client/ audience at whom the applications are aimed at. The cloud applications characteristically differ from the software & web applications in respect of on-demand self-service, broad network access, resource pooling, on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service.

Apart from these differences in technical characteristics of each, software engineering has been first product-oriented and then also process-oriented; web engineering has client-orientation and now cloud engineering is oriented toward open-endedness. Because of changes in the orientations and other differences mentioned above, the set of metrics required, to measure success for intended goals in type of applications, has also ever been evolving. Thus, any approach/ framework for (knowledge-base of) metrics must be flexible.

The proposed framework is flexible enough to incorporate changes with minimum efforts. The framework assumes LISP-like environment and assumes, as mentioned above, single abstract data type (ADT), viz. list (or recursive list). The ADT is not only a data type, but basic program construct also, with the advantage that even programs may be treated as data and can be given as inputs to any program including itself.

Next, the structure of the communication is outlined. Related Literature is briefly discussed in Section 2. The Section 3 contains required details of the proposed approach, which is continuation of the approach proposed in [1], and it also contains some illustrative exemplars. Finally, Section 4 concludes the work reported in the communication.

II. Related Literature

Since the very beginning, around 1998, when web engineering started branching off as an independent discipline from the parent discipline of software engineering [2-4], the activity of designing & defining of web metrics was considered as one of major web engineering activities [5-6]. Early Contributions toward designing appropriate metrics are discussed in two surveys [7-8] and also in [9-10].

Since popular use of web sites as advertisements and point-of-sales components of various enterprises, another type of web measurement, viz. web analytics, similar to but different from web metrics, has been used as a tool for business and market research and to assess and improve the effectiveness of individual websites. A good overview is given in [11]. Other useful references in this respect include [12-15].

Apart from business research, since at least 2006, science of web, or 'web science' as it is called, has also been investigated as a subject of academic pursuit & also as a tool for academic research [16, 17]. Web Science, in its pursuit of understanding and explaining the phenomenon of Web, overlaps a number of disciplines as diverse as sociology, psychology, economics, law, mathematics, and computer science. Hence, it is interdisciplinary in nature. Also, being a science, web science involves a number of metrics. Webometric—a related discipline, rather, a sub-discipline of web science—is, according to one of the definitions of webometrics, the quantitative analysis of web phenomena, using techniques from various fields of study mentioned above [18-20]. It includes link analysis, web citation analysis, search engine evaluation and purely descriptive studies of the web.

Web, which started as only a medium for publishing read-only information, has diversified to find applications in almost any intellectually conceivable domain affecting human life. Some of the very well-known applications include email, VoIP & WhatsApp for communication; YouTube, webcam, FTP etc. for data transfer; Facebook etc. for social networking; and Wikipedia as a free online encyclopedia. It has become significant medium for providing services electronically. All these applications use sound engineering & management principles, and use appropriate metrics for the purpose. In this respect, there is enormous literature. However, for illustration, just one on survey of web service metrics [21] is mentioned.

Recent contributions to literature on web metrics, web analytics and web science include [22-34]. Each of the cited contributions proposes new web metrics, analytics tools, or a platform/framework regarding web metrics/analytics.

III. Outline Of The Framework

In this section, the approach to the proposed framework is discussed in sufficient details. To illustrate the approach, in the next section, a number of exemplars are given.

1.1 The Beginning:

For the sake of explanation, initially, it may be assumed that the disciplines related to Web—from which metrics will be considered to be included in the proposed framework—are web-engineering, web-science & web-applications.

Thus, the proposed framework may be started being developed by considering Web as a list of three elements, viz. (web-engineering, web-science, web-applications). The fact may be expressed in the proposed mathematical (semi-formal) notation

(web (web-engineering, web-science, web-applications)),

As a recursive list, where, instead of 'Web', 'web' also may be used.

It may be noted that the mathematical notation above is almost LISP-like notation.

The above notation is slightly modified by incorporating
(sub-discipline-path (web))

so that the new notation becomes

(i) (web (sub-discipline-path (web)) (web-engineering, web-science, web-applications))

The purpose of the modification is to keep track of the lowest level of sub-discipline at which a metric may be defined/ introduced. The purpose will get more clarified as the development of the proposed framework is explained in increasing details.
Next, in order to demonstrate the flexibility & distributive nature of the proposed approach to develop the framework, let it be later discovered that the web applications are to the fields of commerce, manufacturing, surgery and performing arts.
In view of the fact, the definition (i) above may be extended in either of the following two ways

```
(ii)  (web (
         (sub-discipline-path (web)),
        (web-engineering, web-science,  web-applications)
           )
      )
      (web-applications (
        (sub-discipline-path (web, web-applications)), (commerce, manufacturing, surgery, performing arts)
                         )
      )
                 OR
(iii)

     (web (
           (sub-discipline-path (web)),
          (web-engineering, web-science,
            (web-applications (
              (sub-discipline-path (web, web-applications)),
       (commerce, manufacturing, surgery, performing arts)
                                 )
              )
           )
         )
     )
```

In view of the ease of incorporating modification and ease of human understanding of the modification, most of the time in future, only type (ii) of modification will be used.

It may be noted that parentheses play a significant role in LISP language as well as in proper definitions given above and in those which will be defined later. This is why, only for explanation, the parentheses are spread over a number of lines to show matching of corresponding pairs.

The process of finding and denoting the sub-discipline-path after addition of another level of sub-discipline is quite simple and algorithmic. For example, when sub-discipline web-applications is further expanded as (commerce, manufacturing, surgery, performing arts) then web-applications is appended to the previous sub-discipline-path list (sub-discipline-path (web)) to get (sub-discipline-path (web, web-applications)). At this stage, if there is a metric which is relevant to web-applications, the metric will be introduced here, and sub-discipline-path informs that the introduced metric belongs to web-applications, and the path to reach the sub-discipline viz. web-applications is given by web→web-applications.

In order to explain how the framework is gradually extended to realistic dimensions, let it be further assumed that, in view of the discussion in Section 3.2 below, later web-academics linkage is found to be quite an important application and a source of useful metrics, and it is felt that web-academics linkage needs to be treated independently of web-applications, then the above definition may be further extended. The major benefit of the proposed approach for the framework is that the change in the definition requires minor modification/ extension, as will be explained later. Explanation for why it may be felt that web-academics linkage be treated independently of web-applications, is given in the next section.

1.2 Web as Tool for Academics:

Web is now used not only for publication of read-only information, but even for providing a number of applications & services involving computational & informatics tools. Web has become an essential tool for academic pursuits including research. Web-academics linkages may be broadly put in three categories: (i) Digital, e.g. Digital Humanities [35], Digital Enterprise [36], Digital Economy [37] and Digital Sociology [38]; (ii) Computational, e.g. Computational Humanities [39], Computational Economics [40] and Computational Sociology [41]; and (iii) Informatics-based, e.g. Security Informatics [42-43] and Social Informatics [44].

The differences between three terms—Digital, Computational and Informatics—used as prefix/ suffix may be illustrated through the following examples in context of: (i) money and (ii) an academic discipline, say, sociology

(a) The money available through an electronic valet, e.g. BHIM (Bharat Interface for Money) is digital money, which cannot be touched or transferred physically. The processes that go inside the computers and Internet, which allow the transferring money from one account to other, are computational. The large number of accounts that keep record of the electronic/ digital money available to different persons/ organizations, are stored in large databases. A discipline which allows us to create such large databases so that the accounts are created, updated and maintained properly and efficiently, is called Informatics.
(b) Digital sociology is a sub-discipline of the academic field of sociology. It focuses on understanding the use of digital media as part of everyday life and how these various technologies contribute to patterns of human behavior, social relationships and concepts of the self. Computational sociology is a branch of sociology that uses computationally intensive methods to analyze and model social phenomena. Using computer simulations, artificial intelligence, complex statistical methods, and analytic approaches like social network analysis, computational sociology develops and tests theories of complex social processes through bottom-up modeling of social interactions. Social informatics is the study of information and communication tools (not computational ones) in cultural or institutional contexts.

Assuming that after the above discussion, web-academics linkage is accepted as an independent discipline of web, the required extension in the definition (ii) above viz.

```
 (web (
          (sub-discipline-path (web)),
          (web-engineering, web-science,  web-applications)
      )
 )


(web-applications (
          (sub-discipline-path (web, web-applications )), (commerce, manufacturing, surgery, performing arts)
                )
)
```

may be made in the following way:

```
(iv) (web (sub-discipline-path (web)),
          (web-engineering, web-science,  web-applications, web-academics-linkage) )

     (web-applications (sub-discipline-path (web, web-
```

applications))
(commerce, manufacturing,
surgery, performing arts))

(web-academics-linkage
(sub-discipline-path (web, web-academics-linkage))
(digital, computational,
informatics-based))

The details about web-academic-linkages, if required, may be further added to get the following definition

(v) (web (sub-discipline-path (web)),
(web-engineering, web-science, web-applications, web-academics-linkage))

(web-applications (sub-discipline-path (web, web-
applications))
(commerce, manufacturing,
surgery, performing arts))

(web-academics-linkage
(sub-discipline-path (web, web-academics-linkage))
(digital, computational,
informatics-based))
(Web-academic-linkages (
(Digital(sub-discipline-path (web, web-academics-linkage, digital)) (Digital economy, Digital sociology, web-science, Digital music, Digital humanities, , Digital media, Digital Marketing, ..))
(computational (sub-discipline-path (web, web-academics-linkage, computational)) (Computational science, Computational linguistics, Computational sociology, Computational biology , Computational economics,…)),
(informatics(sub-discipline-path (web, web-academics-linkage, informatics)) (Health informatics, Business informatics, Education Informatics, Social Informatics, …))))
(Digital sociology (sub-discipline-path (web, web-academics-linkage, digital, Digital sociology) (Digital culture, Digital Divide, Digital Literacy))

3.3 Web Search & web analytics

It may be pointed out that the term ‘web search’ is different from the term ‘web analytics’. The two terms differ in the sense that ‘web search’ refers to searching different websites through the Internet for a particular item say ‘computational complexity’, whereas, ‘web analytics’ is about a particular website regarding say, visitors to it. Each of these is part of web science, but, in view of their significance, each may be discussed independent of web science and of each other. Further, web-analytics technologies are usually categorized into on-site and off-site web analytics [15]. In order to incorporate these extensions, the required modification for the purpose, shown below in bold, may be achieved by (a) listing web-search and web-analytics after the entry web-science in the second line of definition (iv) above, and then by (b) adding suitable notation regarding web-analytics. The extended definition of web becomes

(iv) (web (sub-discipline-path (web)),
(web-engineering, web-science, web-search, web-analytics, web-applications, web-academics-linkage))

(web-applications (sub-discipline-path (web, web-
applications)),
(commerce, manufacturing,
surgery, performing arts))

(web-academics-linkage
(sub-discipline-path (web, web-academics-linkage)),
(digital, computational, informatics-based))

(Digital (sub-discipline-path (web, web-academics-linkage, digital)), (Digital economy, Digital sociology, web-science, Digital music, Digital humanities, , Digital media, Digital Marketing, ..))

(Digital sociology (sub-discipline-path (web, web-academics-linkage, digital, Digital sociology) (Digital culture, Digital Divide, Digital Literacy)).

(computational (sub-discipline-path (web, web-academics-linkage, computational)) (Computational science, Computational linguistics, Computational sociology, Computational biology , Computational economics,…)),
(informatics(sub-discipline-path (web, web-academics-linkage, informatics)) (Health informatics, Business informatics, Education Informatics, Social Informatics, …))))
(web-analytics (sub-discipline-path (web, web-analytics),
(on-site-analytics, off-site-analytics))

3.4 Concurrent & Distributive Nature of the Approach

The discipline of World Wide Web, or just web, like many other disciplines, may be viewed and approached from different perspectives: Each perspective leading to possibly different classifications of issues, sub-disciplines, tools, technologies and metrics etc.

On the basis of the discussion in the section so far, one of the perspectives of the web is that it be treated to be composed of top level six elements: web-engineering, web-science, web-search, web-analytics, web-applications, web-academics-linkage. (Obtained from Definition (vi) above). Accordingly, the definition of web at the top-level in the mathematical notation is

(v) (web (sub-discipline-path (web)),
(web-engineering, web-science, web-search, web-analytics, web-applications, web-academics-linkage))

The top-level characterization of web given above may be a general one. However, when the concern for types of the web sites is the dominant issue, the characterization of web from the new perspective may begin as follows

(vi) (web (sub-discipline-path (web)),
(educational, news, informational, knowledge,
social network, ecommerce, entertainment,
hospitality, manufacturing, banking, …))

The sub-fields/concerns mentioned in (vii) at top level may occur somewhere down in characterization (viii). The proposed approach allows both the characterizations to coexist, and the concurrent & distributive functional programming environment would start executions of programmed versions of both concurrently. The results of whichever one reaches the desired result/ metrics, or even results of both if available, will be displayed.

One of the advantages of the approach is to allow developers to look at the task from different perspectives. Even different members of developer team may start working on appropriate mathematical models from different perspectives independent of each other.

3.5 Characterization of Metrics in the Framework:

In the definitions of the proposed framework, so far, only disciplines & sub-disciplines of web are enumerated. However, during the process of extending definitions, a stage reaches when relevant to a particular discipline/ sub-discipline, definition/ algorithm of a particularly metric ultimately needs to be given and inserted in the framework.

In the proposed framework, a metric may be characterized as a recursive list as follows:

((attribute-name-1, attribute-value-1), (attribute-name-2, attribute-value-2), …. (attribute-name-k, attribute-value-k), …),
where, some of the attribute- values may links-addresses.
For example,

((name-of-metric, ???) (sub-discipline-path (web, top-sub-discipline, next-level-sub-discipline,….)) (source-of-metric, ???), (definition-or-algorithm-of–metric, ???) (link-to-executable-code-of-metric, ???))

The entry (sub-discipline-path (web, top-sub-discipline, next-level-sub-discipline,…)) may not be required, as it is already determined by the location of the characterization of the metric.

IV. Illustration With Concrete Exemplars

In this section, the process of incorporation of known metrics at appropriate locations in the framework starting from some top-level definition of web, is explained through two concrete examples.
In order to simplify the explanation, the notation (vii) will be used as the top-level characterization of web

(vii) (web (sub-discipline-path (web)),
(web-engineering, web-science, web-search, web-
analytics, web-applications, web-academics-linkage)
)

4.1 Web Science & Metrics

One of the surveys of web metrics [45] is based on the study of web as web-science or as web-informatics, as the science of measuring all aspects of improving Web's capacity for serving information more effectively. Web science implicitly involves study of quality and usefulness of Web resources and services. This observation points towards measurements and models that quantify various attributes of web sites.

According to this web science aspect of Web, Web metrics are classified as Graph Properties metrics, Significance metrics, Similarity metrics, Search metrics, Usage metrics, Information Theoretic metrics.

Then metrics regarding Graph Properties, Significance, Similarity, Search are further considered as follows. Graph Properties metrics are classified as Centrality metrics, Global metrics, Local metrics. Significance metrics are classified as Relevance metrics, Quality metrics. Similarity metrics are classified as Content metrics, Link metrics. And, Search metrics are classified as Effectiveness metrics, Comparison metrics.

In view of the discussion, the definition/notation (vii) will be modified through expansion of web-science as follows:

(ix) (web (sub-discipline-path (web)),
(web-engineering, web-science, web-search, web-
analytics, web-applications, web-academics-linkage)
)

(web-science ((sub-discipline-path (web, web-science)), (…, …, web-metrics, …, …)

(web-metrics ((sub-discipline-path (web, web-science, web-metrics), (Graph-Properties-metrics, Significance-metrics, Similarity-metrics, Search-metrics, Usage-metrics, Information-Theoretic-metrics))

(Graph-Properties-metrics (sub-discipline-path (web, web-science, web-metrics, Graph Properties metrics)), (Centrality-metrics, Global metrics, Local metrics))

(Significance-metrics ((sub-discipline-path (web, web-science, web-metrics, significance-metrics), (Relevance-metrics, Quality-metrics))

(Similarity-metrics (sub-discipline-path (web, web-science, web-metrics, similarity-metrics), (Content-metrics, Link-metrics))

(search-metrics (sub-discipline-path (web, web-science, web-metrics, search-metrics), (effectiveness-metrics, comparison-metrics))

4.1.1 centrality-metrics For the sake of explanation, centrality-metrics of the class of Graph-Properties-metrics are considered for insertion in the proposed framework, the following notation is appended to definition (ix) above to get definition (x)

(x) … Notation (ix) …
(Centrality-metrics (sub-discipline-path (web, web-
science, web-metrics, Graph Properties metrics,
Centrality-metrics)),

(Centrality-metrics-definition-texual
(“Centrality measures reflect
the extent of connectedness of a node with respect to other nodes in the graph. They can be used to define hierarchies in the hypertext with the most central node as the root. The out distance (OD) of a node i is defined as the sum of distances to all other nodes; that is, the sum of all entries in row i of the distance matrix C. Similarly, the in distance(ID) is the sum of all in distances. In order to make the above metrics independent of the size of the hypertext graph, they are normalized by the converted distance or the sum of all pair-wise distances between nodes thereby yielding the relative out centrality (ROC) and the relative in centrality (RIC) measures, respectively.”)),

(Centrality-metrics-definition-formulae ($OD_i = \sum_j C_{ij}$, $ID_i = \sum_j C_{ji}$, $ROC_i = \frac{\sum_i \sum_j C_{ij}}{\sum_j C_{ij}}$, $RIC_i = \frac{\sum_i \sum_j C_{ij}}{\sum_j C_{ij}}$ R)),
(Centrality-metrics-definition-code, link-to-executable-code))).

It may be noted that in view of the three definitional parts being not large, these are completely given as part of the notation. However, in general, instead, a cross-reference or a hyperlink as (definitional-link, link-address) is given in notation, from where one may go through link-address to the required location to find all these details. In the next subsection, web metrics are examined from web engineering perspective.

4.1.2 PageRank Metric/Algorithm

PageRank is a metric/algorithm used by the well-known Google search engine for measuring the importance of website pages. It is being discussed here not only in view of its significance as an algorithm, but also, to illustrate another aspect of the proposed framework. In the discussion of centrality-metrics above, the fine details of various components like Centrality-metrics-definition-textual etc. of Centrality-metrics were included as textual part of the definition. However, the required details may be voluminous and difficult to accommodate to be effective, at least. The alternative is to store the required details in a file/ folder and, in the definition only the link to the file/ folder may be incorporated.

For example [46-50] are found to be relevant & useful for the up-to-date discussion of PageRank, details of these references me put in the file created for the purpose. Further, let the required information may be already available on WWW and other websites [51-53], in that case, hyperlink to the website/ webpage may be incorporated in the file/folder. Also, the file/folder created for the purpose contains all the details similar to those given in definition (x) above. Thus, according to this scheme, the definition of PageRank may be given as

(PageRank ((sub-discipline-path (web, web-
science, web-metrics, …, PageRank), (details-of-PageRank, link-to-PageRank-file)).

4.2 Web Engineering & Metrics

The following discussion is to illustrate the parallel & distributed nature of the framework, in the sense that the same concept or topic may be viewed, & denoted in the framework, from different perspectives. For example, the PageRank issue, treated as an issue of web-science, may also be treated as an issue of web engineering as explained below. Further, instead of treating PageRank as atomic, it may be considered as composed of a number of parameters, including page cohesiveness [54, section 2.1.1]. The detailed discussion in this regard follows.

According to another web metrics survey (using Web Quality Model (WQM)) proposed in [55], web-engineering can be considered as constituted of three top level elements viz. Web-Features, Quality-Characteristics, Life-Cycle-Processes. Each of which, in turn, can be considered as constituted of top level elements as follows:

Web-Features of Content, presentation, Navigation; Quality-Characteristics of functionality, reliability, usability, efficiency, portability, maintainability; and Life-Cycle-Processes of development, exploitation including the operative user support, maintenance process including web site evolution.

Thus, definition (vii) may be further enhanced as

(xi) (web (sub-discipline-path (web)),
(web-engineering, web-science, web-search, web-
analytics, web-applications, web-academics-linkage)
)

(web-engineering (sub-discipline-path (web, web-engineering)),
(web-features, quality-characteristics, life-cycle-processes))

(web-features (sub-discipline-path (web, web-engineering, web-features)) (Content, presentation, Navigation))

(quality-characteristic (sub-discipline-path (web, web-engineering, quality-characteristic)) (functionality, reliability, usability, efficiency, portability, maintainability))

(life-cycle-processes (sub-discipline-path (web, web-engineering, life-cycle-processes)) (development, exploitation, maintenance process))

Next, PageRank metric/ algorithm may be considered as leaf node of sub-discipline hierarchy: web →web-engineering→ quality-characteristic→efficiency→PageRank.

Further, cohesiveness (of a web-page) is considered as significant component of PageRank, so that the above sub-discipline hierarchy may be considered as web →web-engineering→quality-characteristic→efficiency→PageRank →cohesiveness. Next, the following definition/ notation for cohesiveness may be incorporated, according the preceding explanation, at appropriate place in the notation for the framework:

$$\frac{\frac{N*(N-1)}{2}\frac{M*(M-1)}{2}\sum\sum Wij*Pij}{\frac{N*(N-1)}{2}} \quad (i,j = 0, N-1, i < j)$$

.

V. Conclusion

Metrics play significant role in any engineering task, hence, so do web metrics in web engineering. For automating web design as component of web engineering, it is desirable to create a knowledge base of metrics, which allows quick access to the appropriate metrics, and which is flexible enough to allow modifications when required. Using LISP-like notation, a framework is proposed for the purpose. Using the approach, a knowledge base consisting of definitions, tools, techniques, algorithms, executable codes etc. may be created for automating web design.

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