A Novel Approach for Realizing Business Agility through Temporally Planned Automatic Web Service Composition using Network Analysis

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Abstract – *The building block of Service Oriented Architecture is web services. Web services are self contained, self describing, modular applications that can be published, located and invoked across the web. Composite services are built by aggregating elementary services by a process called web service composition. Web service composition can be classified into manual and automatic types. The first type involves design time composition when the architecture and design of the software system is planned. The second type automatic service composition involves composing web services automatically to facilitate ease of composition process for engineers. Automatic composition is generally guided by dynamic composition to handle non determinism at run time. Automatic composition can be materialized as an artificial intelligence planning problem. Planning represents a part of the world as states and changes in those states. Business agility is the ability of business to adapt efficiently and cost effectively in response to the changes in the business environment. The changes in business environment are temporal. In this paper we have devised a new algorithm called Opus deviser which targets to achieve business agility through web service composition that is temporally planned using PERT Network analysis.*

Keywords: *Automatic Web Service Composition, Temporal planning, Network analysis, Programme Evaluation and Review Technique (PERT), Opus Deviser Algorithm*

1 Introduction

Any innovation requires change. In business changes are imperative. Business changes can be incremental, business led and collaborative. Service Oriented Architecture makes changes easier. Service Oriented Architecture is an Information Technology architectural style that supports integrating business as linked services. Service Oriented Architecture increases customer access to company resources and information, and improve customer retention through faster sales. It enhances business decision making and employee productivity. Business agility means having the capability to react to incoming request and changes in a timely manner. Any business becomes agile when it is quickly run to take advantage of the best opportunities. For example when the client requests for a service which suits our service range then the agile business should react to this request and develop an adapted version that meets the client's needs. Many changes in a business environment are based on time. For example costing of a product can be based on time or delivery of products can be based on time, reordering raw materials can be based on time, etc. Business agility is therefore quasi temporally driven. A recent survey by Microsoft suggests that 87% of CIO's suggest Service Oriented Architecture as the next significant enterprise software to gain business agility [1]. The building blocks of Service Oriented Architecture are Web Services. Service Oriented Architecture composite applications are built by aggregation of elementary services. As the business environment is dynamic to time factor web service composition has to be dynamic and automated to offer business agility. Business agility can thus be rendered through temporal planning for service composition to build dynamic and automatic composite applications.

2 SOA and Business Agility

Business does not function in vacuum. Business is sensitive to external factors or influences. The external factors affect the internal functions, objectives and strategies of business. Business environment is influenced by degree of competition; social, legal, economical, political, technological and ethical factors. The external environment changes temporally. Temporal changes include customer developing new needs, new competitors enter the market, new technologies are introduced, world - wide event occurs, government introduces new policies, and so on. Changes pertain to cultural factors as well. Business should react to these temporal changes or lose business. Business reactions could include reducing prices, improving quality, spend more on promotion or cut cost. Organizations must be tight in executing today's activities and loose in adapting to future survival. Service Oriented composite applications are loosely coupled. To cope up with the changes in business environment business agility is the need of the hour. We aim to achieve business agility through Service Oriented Architecture where composite applications are built by temporal planning to adapt to changes in business environment. The composition process is done in an optimal and reliable manner using PERT Network analysis.

3 Web Service Composition

Web service composition refers to the process of collaboration of heterogeneous web services. B2B composite applications can be built from composition of services offered by multiple business partners based on business processes. Web service composition is aggregation of elementary or composite web services.

Web service composition refers to the integration of more than one web service to realize business functionality.

Web service composition can be basically classified in two ways. The first type of classification is as static and dynamic composition. The second type of classification is as manual and automatic composition. Most of the web service composition is a weaving of dynamic and automatic web service composition. Dynamicity deals more with the non determinism of the availability of a web service while automatic composition is composing of services done automatically by an agent for ease of development to the engineers. *Automatic Composition* is a composition that is done automatically by agents. Some artificial Intelligence planning algorithm is harnessed to perform automatic web service composition. A typical example OWLS XPlan2.0 where Xplan is a planner based on Hierarchical Task Network planning.

4 Literature Survey

Some of the familiar planners used for web service composition are listed below. FF [2], FF-Metric and HSP 2.0 are state space based planners. IPP, DPPLAN, LPG, PropPlan are graph plan based planners [3]. STAN4 is based on both graph plan and state space plan. UCP OP is a partial order planning based planner [4]. BLACKBOX is a planner based on SAT plan and graph plan. LGP is based on SAT plan. SHOP2 planner is based on Hierarchical Task Network planning [5]. MIPS is based on planning as model checking [6]. The popular web service composition tools are SeGSec, E-flow (HP), Aurora, STONE, ICARIS, Self-Serv, Composer, Ninja, SWORD, SHOP-2, Theseus, Argos, Proteas, Fusion, Astro, Synthy (IBM), etc [7].

RESCUERS: A framework for reliable web service composition developed in July 2009 is based on Critical Path Method [8].

The drawback of this approach is that the activity duration must known in prior which does not occur in reality. Moreover the time deadline for goals and activities in a business environment is dynamic where CPM becomes unsuitable. The probability of completion is not estimated in CPM. In this paper we put forth to use PERT for planning of web service composition that is temporally driven. Our approach generates an optimal and reliable solution enabling to achieve business agility.

5 Corporate Planning – A Time Driven Concept

Corporate planning is the process of deciding the overall objectives of the company as a whole and selecting the ways and means for achieving these objectives. Corporate planning is needed to achieve business agility.

“Corporate planning is a formal, systematic, managerial process organized by responsibility, time and information to ensure that operational planning, project planning and strategic planning is carried out regularly to enable to management to direct and control the future of the enterprise”. – Basil W. Denning [9]

Corporate planning therefore is a time driven concept.

“Corporate planning is a systematic and disciplined study designed to help identify the objective of any organization, determine an appropriate target, decide upon suitable constraints and devise a practical plan by which the objective may be achieved”. – John Argenti [9]

Corporate planning therefore needs to devise a plan with time factor. There are several planning algorithms but as corporate planning and business agility is time driven we choose temporal planning as our approach for web service composition. Web service composition is therefore thriving in a dynamic environment where we use temporal planning to generate automatic composition plan. Service Oriented Architecture is a best way to render business agility.

6 Temporal Planning

Temporal planning means planning with time based and concurrent actions. According to Dana Nau in reality actions and events occur over a time span. Preconditions do not occur only in the beginning. Actions will require maintaining partial states. Goals can be time bound [10].

7 Temporal Planning Aspects

Classical planning does not annex temporal elements. In a real world environment actions and effects are time dependent. An ideal planner must design a plan that augments the temporal features and execute actions and generate effects in proper duration. Plans can change at some period of time. Plan schemes have to be altered to external events based on time. Classical planning cannot plan concurrent actions. Temporal planning needs to generate plan that executes several actions executed concurrently. Goals of a plan are also temporally driven. A plan for instance needs to meet deadlines. A corporate environment is totally driven temporally as it has time related actions, effects and goals. Some business action need to be performed concurrently and relies on external events that are time allied.

8 Composition Planning Using PERT Network Analysis

Network analysis is used for planning projects by analyzing project activities. While planning a project, Network analysis meets the temporal planning aspects. PERT Network analysis breaks down a project into individual tasks or activities and arranges them into logical sequence. The activities can be performed concurrently or in other sequence. The time required to complete activities in certain projects is generally not known in priori. PERT Network analysis incorporates uncertainty in activity times during analysis. PERT is used to determine the probabilities of completing the various stages of the project with specific deadlines. PERT is also used to calculate the expected time to completion of a project. Web service composition is also a planning problem. In this paper we use PERT Network analysis as a novel approach to plan the temporal aspects of temporal planning to achieve business agility. We use PERT Network analysis to determine which web services should be sequentially executed during composition, schedule the execution of the composed web services and plan the completion of the entire composition within the specified deadline.

9 Overview of Our Approach

Business environment is dynamic. The dynamicity is highly driven by time. Composing web services to create a composite application achieves business agility when the dynamic and time driven factors are taken into account. Web service composition now is a planning problem. Network analysis is used for planning projects by analyzing its activities. Therefore we use PERT Network analysis which assumes that the activity times are not known in prior in a dynamic business environment to plan the composite application unlike CPM. All possible combinations of web service compositions are calculated with reference to goal deadline and verified if activity deadline is met. The matching compositions are chosen and the probability of project completion is compared and the most suitable composition is selected by selection module and executed. We choose PERT Network analysis as it considers the uncertainty of time which is a typical business environment. CPM on the other hand assumes that the activity time is known in prior which is not a typical business agile environment.

10 Opus Deviser – Algorithm

Algorithm - Opus Deviser

Input: Set of Web Services

$$W = \begin{Bmatrix} w11 & \cdots & w1n \\ \vdots & \ddots & \vdots \\ wm1 & \cdots & wmn \end{Bmatrix} \text{ where}$$

m – Number of web services in each category

n – total number of service categories that make up a composite application,

Goal deadline (g),

Activity deadline set T = $\{t_1,t_2,\ldots,t_{n-1}\}$

Categorical sequence CSeq = $\{C_1 \rightarrow C_2 \rightarrow \ldots C_n\}$

Output: Composite service S

Begin

01 Generate all possible combinations of web service compositions from set W such that there is one service from each category in the sequential order specified by CSeq. The number of combinations nc = $(mC_1)^n$ (1)

02 For each combination perform a PERT network analysis

a. Assume optimistic time (a), most likely time (l) and pessimistic time (b) or each activity based on web service execution environment
a – Shortest possible time for each activity to be completed by the web services
l – The time the activity will most likely take to complete the activity by the web services
b – Longest possible time for the activity to be completed by the web services

b. Compute the expected duration set TC = $\{tc_1,tc_2,\ldots,tc_{nc}\}$ for all combinations of web service execution for each activity from a, l and b such that
$tc_c = \{te_1,te_2,\ldots,te_{n-1}\}$
$te_d = (a+4l+b) / 6$ (2)
where c is a combination and d is an activity

c. Create a directed graphical representation for each combination such that each node is an event and arrow line is an activity. Each web service of a combination on execution performs an activity and consumes time. The computed expected duration set is represented in the generated graphs of every combination.

d. Compute the variance set VC for each activity in each combination.
$VC = \{vc_1,vc_2,\ldots,vc_{nc}\}$
$vc_c = \{v_1,v_2,\ldots,v_{n-1}\}$
$v_d = ((b-a)/6)^2$ (3)

e. Generate the critical path set CP for every combination. The critical path is the expected project completion length. Critical path is the maximum of the sum of all the paths from start to finish in each graph.
$CP = \{cp_1,cp_2,\ldots,cp_{nc}\}$

f. Compute the set of variance TV = $\{tv_1,tv_2,\ldots,tv_{nc}\}$ of critical path for each combination as the sum of variance of each activity in the critical path.
$tv_c = \sum_{d=1}^{n-1} v_d$ (4)

g. Compute the set of Standard Deviation SD = $\{sd_1,sd_2,\ldots,sd_{nc}\}$ of the project length for each combination.
$sd_c = \sqrt{tv_c}$ (5)

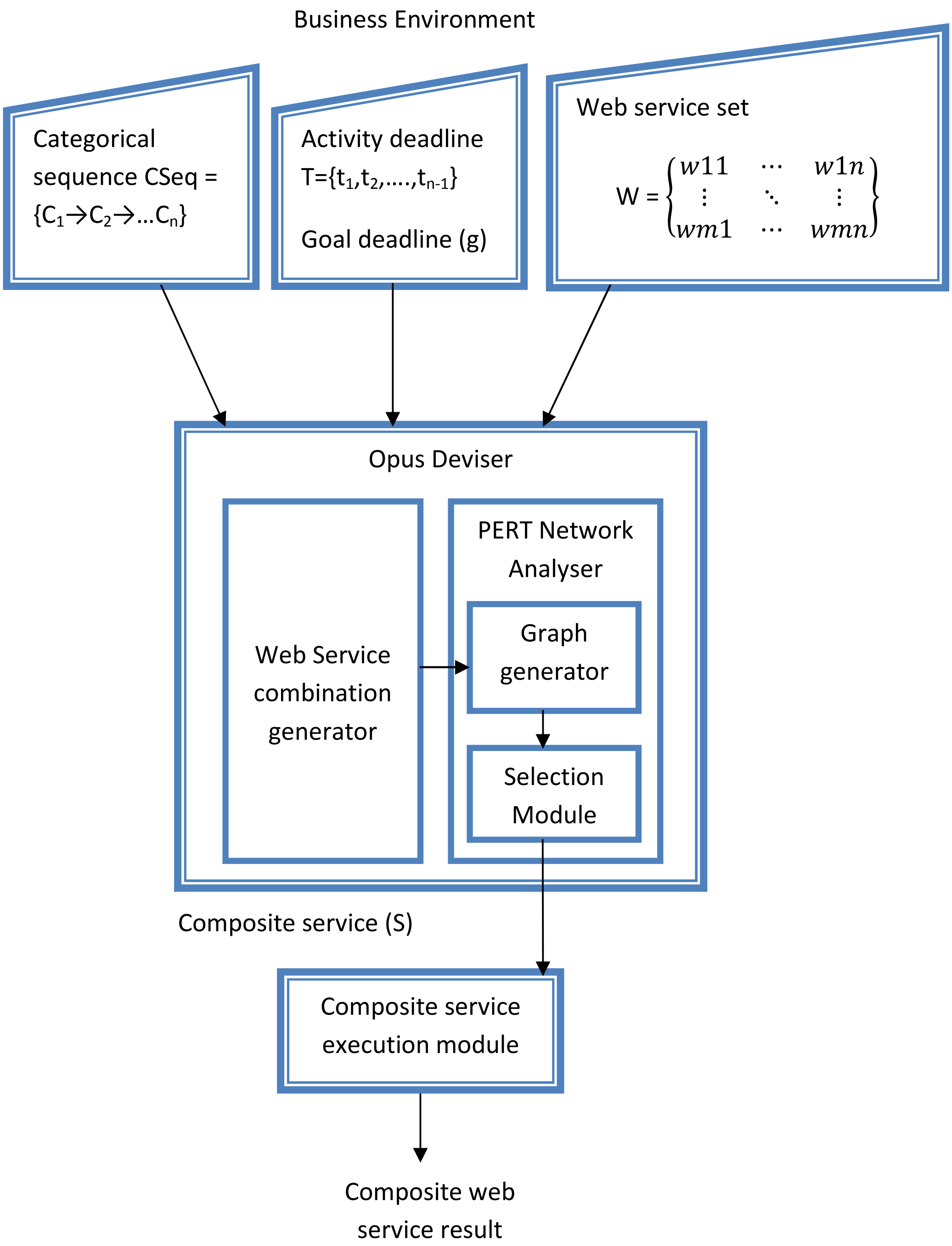

Fig. 1: Opus Deviser – Block Diagram

h. To plan with the goal deadline assign time under consideration X to goal deadline. X=g

i. Compute the set of standard normal variate
$Z = \{z_1, z_2, \ldots, z_{nc}\}$ for all combinations.
$z_c = (X - \bar{x}_c)/sd_c$ (6)
X – Time under consideration (goal deadline)
$\bar{X}_c$ - Mean (Length of critical path)
sd_c – Standard deviation of critical path of a combination.

j. Find the probability that the project will be completed within the completion time from the table of probability values for normal distribution.
$A = \{a_1, a_2, \ldots a_{nc}\}$ When $Z \geq 4.09$ the probability of completion becomes 1.

03 Check the set of probability of completion of the project A from step (02 j) and choose the best combination S such that it has high a_c so that the composition is reliable and in case more than one combination has same a_c value check for its Critical path and select the combination with minimum cp_c such that the composition is optimal.

04 Execute the combination S.

05 End

11 Experimentation and Results

Inputs:

CSeq = {$C_1 \rightarrow C_2 \rightarrow \ldots C_n$}

$$W = \begin{Bmatrix} C1 & C2 & C3 \\ w11 & w12 & w13 \\ w21 & w22 & w23 \end{Bmatrix}$$

T = { 40, 50 } (min)   g = 90 min

Opus Deviser – Web service combination generator

m = 2 and n = 3   nc = $(2C_1)^3$ = 8

Generate 8 possible combinations

Table 1: Table of a, l and b for calculating TC

Activity	a	l	b	Expected Duration
A1	30	50	60	48.33
B1	30	50	60	48.33
A2	30	50	60	48.33
B2	40	60	70	58.33
A3	20	40	40	36.67
B3	20	40	50	38.33
A4	20	40	40	36.67
B4	30	40	40	38.33
A5	30	40	40	38.33
B5	20	40	50	38.33
A6	30	40	40	38.33
B6	30	40	40	38.33
A7	40	55	50	51.67
B7	40	60	70	58.33
A8	40	55	50	51.67
B8	30	50	60	48.33

Calculate expected duration set TC based on a, l and b in minutes.

TC = {{48.33,48.33},{48.33,58.33},{36.67,38.33},{36.6,38.33},{38.33,38.33},{38.33,38.33},{51.67,58.33},{51.67,48.33}}

Opus Deviser - Graph Generator:

Generates the graph and assigns the expected duration set. The graph should not have loops, cross over and recursion. The graphs should be sequential.

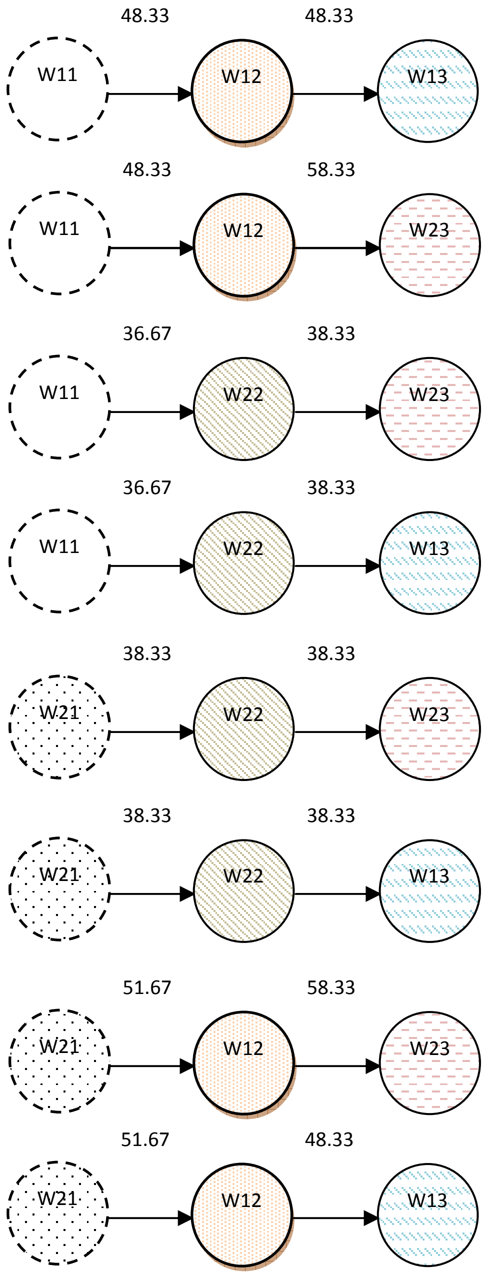

Fig. 2: Graphs for each combination

Calculate the critical path set CP

CP = {96.66,106.66,75,75,76.66,76.66,110,100}

Calculate the variance for each activity in each combination.

VC = {{25,25},{25,25},{11.11,25},{11.11,2.78},{2.78,25},{2.78,2.78},{2.78,25},{2.78,25}}

Total Variance set TV = {50,50,36.11,13.89,27.78,5.56,27.78,27.78}

Assign goal deadline to time under consideration X.

X = 90 min

Calculate standard deviation set SD = {7.07,7.07,6,3.73,5.27,2.36,5.27,5.27}

Calculate the set of Standard normal variate Z

Table 2: Calculation of Z for each combination

X	Length of Critical path	SD	Z
90	96.66	7.07	-0.94
90	106.66	7.07	-2.36
90	75	6	2.50
90	75	3.73	4.02
90	76.66	5.27	2.53
90	76.66	2.36	5.65
90	110	5.27	-3.80
90	100	5.27	-1.90

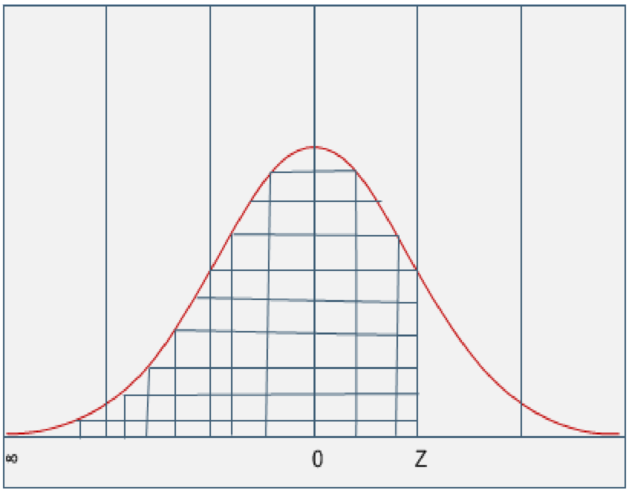

Fig. 3: Area under the curve from ∞ to Z

Calculate the probability of completion of the project from the Z - table of probability values for normal distribution.

area3=0.9938, area4=1, area5=0.9943, area6=1

The selection module finds that combination 4 and 6 are highly reliable as its probability of completion is 1. The module needs to select any one composition for execution. So it looks at the length of the critical path for combination 4 and 6 which is 75 and 76.66 respectively. Composition 4 takes only 75 minutes to complete the composition and therefore is optimal to choose. The composition w11→w22→w13 is selected and executed. In case the probability of completion and the length of the critical path also the same for more than one composition then any one composition is randomly chosen and executed. The compositions with negative Z values are taking more time than the goal deadline and are therefore discarded.

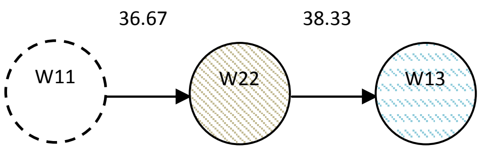

Fig. 4: Selected combination for execution

12 Discussion

In real world the time for completing an activity is not deterministic. The completion time of most of the activities is highly uncertain. PERT treats activity time as a random variable. PERT considers project completion in a probabilistic approach. PERT estimates expected project completion time; probability of completion of project before a goal deadline; the critical path and activity deadlines. Therefore Opus deviser based on PERT is more advantageous than using CPM based service composition planning.

13 Conclusion and Future Enhancement

We have proposed Opus deviser as an automatic, quality driven web service composition algorithm that is in synchronization with business issues that are time driven. We have developed the planner to choose the best composition based on PERT probability predictions which more realistic to CPM based approach. Thus the Opus deviser generates an optimal and a reliable plan. Anyhow PERT is comparatively subjective. PERT does not consider that if some activities are delayed then other paths can become critical. We can enhance the algorithm as a future work using Monte Carlo simulations to handle this issue. Monte Carlo simulation is a method where we analyze uncertainty propagation by determining how random variation, lack of knowledge or errors affect the sensitivity, performance and reliability of the system being modeled [11].

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