ISSN : 0974 - 7435 Volume 10 Issue 5

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 10(5), 2014 [1337-1344]

Pi calculus-based semantic web service combination formalization description and validation research

Huang Lei[1,2]*, Wu Yanpeng[1,2], Zhu Qunfeng[1]

[1]Department of Information Engineering, Shaoyang University, Shaoyang 422000, Hunan, (CHINA)

[2]Provincial Key Laboratory of Informational Service for Rural Area of Southwestern Hunan, Shaoyang University, Shaoyang 422000, Hunan, (CHINA)

ABSTRACT

Semantic Web and Web service techniques combination generates semantic Web service, the service refers to the semantic that applies semantic Web markup languages to describe service, so that lets web service to be transformed into computer comprehensible entity, supports service combination, autodiscovery and implementation, therefore semantic Web service-based automatic composition technique target is applying software with users demands to make automatic composition of various existed Web service so as to cooperate work and fulfill users tasks. In semantic Web service combination research field, formalization description and service combination accuracy validation is a very important problem, in the problem, it involves lots of Web service communication collaboration as well as inference, and Pi calculus due to its strong expressive ability and simple mathematical structure superiorities, is thought to be a kind of mature process algebra method, the method has mobile description mechanism, therefore its application in Web services communication and interaction is by far a kind of relative mature and implementable method. The paper analyzes semantic Web service combination form, accuracy validation and Pi calculus principle; it puts forwards Pi calculus formalization and validation –based semantic Web service automatic composition method, and gets accuracy and reliability superiority degree that applies the method in semantic Web service automatic composition.

KEYWORDS

Semantic Web service;
Process algebra;
Pi calculus;
Modeling.

INTRODUCTION

Web service belongs to a kind of software components that has autonomic behaviors, it can be called, looked up and issued in Internet, and is a kind of service-oriented architecture, its main research purpose is combining existing multiple services for users implementing 'on-demand service', therefore service-oriented architecture implements autonomic task executing ability, distributed system cross-language, loose coupling and cross-platform service purpose on the basis of connecting with Internet. By far, international and domestic academic circles and industrial circles have organized deep researches on semantic Web service. For the reasons that semantic Web service can automatically be discovered, executed and combined is because the service has semantic information, loose coupling and high integratable abilities. Researchers and institutes in all places around the world have constantly researched on semantic Web theoretical practice and standard specifications, especially for W3C semantic service group that has made unsurpassed contributions during the service development process. Service combination strategy and matching algorithm is the core of semantic Web service theory researching, in the aspect of theory, lots of researchers have provided a great deal of academic achievements. Among them, regarding formalization method, someone proposed to use Petri network theories, AI programming and process algebra as well as other methods to make ontology description on semantic Web service, in the hope of implementing automatic Web combination problem, and use formalization method to implement and reasonable verify Web service. The paper proposed method is based on Pi calculus method, the method is a concurrence theory that proposed by Robin Milner, the method has mobile description mechanism and strong expressive ability as well as simple mathematical structure these advantages, therefore apply Pi calculus to describe Web services communication and interaction is feasible.

Name is the quotation to object in case that a process and other processes connections as well as their possessed other processes instructions can use the process possessed free name to make characterization. Pi calculus is using code to define all basic functions and complicated data types and takes them as basic objects to handle, and applying process algebra to describe parallel system, let it can make certain analysis of service existing expected behaviors. When apply mutual interactive set to describe Web combination, it can verify Web service combination survival and safety periods' some features. For semantic Web service combination key technologies, lots of professionals have made efforts, researches in academic aspect, it has: Fu Peng-Bin, Li Li-Bo and Yang Hui-Rong from Beijing University of technology's school of computer in "Graph plan-based semantic Web service automatic combination method", they according to service requesters' specific demands, proposed a kind of Graph plan-based semantic Web service automatic combination method, the method on the basis of establishing pioneer and successor execution relations knowledge base, it used graph plan forward expanding thought and graph plan solution searching thought, implemented automatically finding out service combination schemes that met users demand from service library, the method comprehensively considered service semantic and service combination efficiency and other factors, on the premise that quality was ensured, according to service requests, implemented service automatic combination and finally used simulation experiment to verify the method validness and feasibility[1]; Li Zhen, Yang Fang-Chun and Su Sen from Beijing University of Posts and Telecommunications network and exchange technology national key laboratory in "Fuzzy multi-attribute decision-making theory-based semantic Web service combination algorithm", they presented algorithm that solved comprehensive evaluation data isomeric service quality global optimal execution plan problems selection, the algorithm could evaluate Qos information that was described by real number, interval number and language type data, so that carried out comprehensive decision-making, on the basis of introducing language type data defuzzification, isomerism decision-making matrix standardization and Qos comprehensive evaluation, they also introduced an expandable ontology that was used to describe isomeric Qos data, and finally used real service quality data to test, and verified the algorithm superiority and validness[2]; Cui Hua, Ying Shi, Yuan Wen-Jie from Wuhan University software engineering national key laboratory and Hu Luo-Kai from Hubei second normal college computer engineering department in "Semantic Web service combination generalization", firstly they concluded and summarized semantic Web service relative basic concepts, outlined semantic Web service combination research contents and targets, and then according to semantic Web service combination used methodology to classify them and analyze these methods implementation process and features, and finally summarized full text and pointed out next step research orientations[3]; Chen Ding-Jian, Wu Jian, Ma Man-Fu and Hu Zheng-Guo from Northwestern Polytechnical University School of Computing in "Semantic Web service credibility model", firstly defined semantic WEB service features and credibility with Web service features, on this basis, they expanded current UDDI, proposed Semantic Web service credibility concept model, and deepen researched on relative algorithms and their implementation schemes, compared with other Web service credibility mechanism, got that the model's advantage was adding semantic information into service credibility targeted semantic Web service features, and integrated three parties authorities evaluation that let credibility to be more effective and accurate[4]. The paper on the basis of previous researches, analyzes semantic Web service combination forms, accuracy validation and Pi calculus theory, proposed Pi calculus formalization and validation-based semantic Web service automatic combination method, got the accuracy and reliability superiority degrees by applying the method in semantic Web service automatic combination, which provides an orientation and method for semantic Web service combination development.

RELATIVE THEORETICAL BASIS

Web service combination basic frame

WSDL, SOAP and UDDI are Web service core supporting technology, Web service supplier, service requester, service agency and XML format information transmission mechanism and their communication composed Web service basic frame. In general, apply UDDI searching and issuing service, use WSDL to make normalized description on Web Service, and SOAP can carry out categorization and structured information exchange in distributed calculation environment in the form of XML. Web service basic frame is as Figure 1 show.

In Figure 1, it showed Web service basic framework, Web service is a distributed computing protocol, service supplier and service requester belong to service combination system two kinds of participants, the later purpose is using former provided Web service, former issues usable Web service, as Figure 2 showed a service automatic combination frame, in the

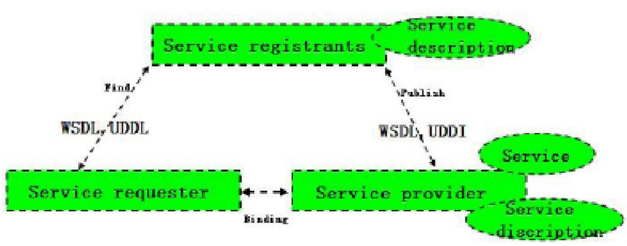


Figure 1: Web service basic framework

frame, it describes Web service and Web behavior by using formalization method. In Figure 2 system frame, it mainly includes :Execution Engine, Service Repository, Process Generator, Translator and Evaluator five components.

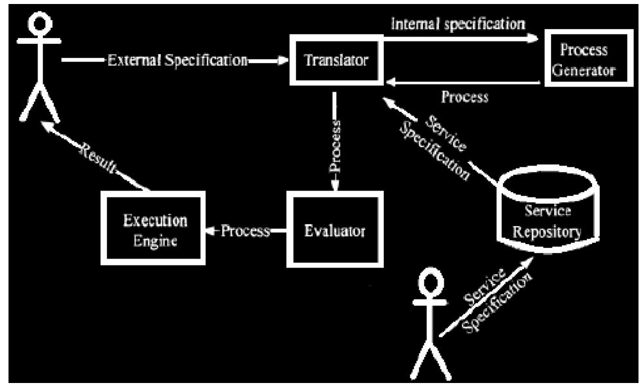


Figure 2 : Automatic service combination framework

Among them, Execution Engine expresses executing engine, the component usage is executing selected service; Service Repository expresses service warehouse, the component usage is storing service information; Process Generator expresses behavior simulation generator, the component usage is analyzing users requesters service requests, and obtain usable service from service repository, and then according to demand, it plans service combination in the hope of meeting users demands; Translator expresses interpreter, the component usage is converting participants practical descriptive language into Process Generator comprehended internal formalization language;Evaluator expresses model evaluator; the component usage is making evaluation on service combination targeted users demand from the aspects of behavior model service quality guarantee and others.

Pi Calculus syntax definition

Process identifier is using capital letter A, B, C, D, E and others to express, let N to express a infinite name set, use u, v, w, x, y, z and other small letters to express the name in name set, P, Q, R, S and others express process expression, process expression has sum form, parallel expression, prefix expression, process identifier, matching expression and restriction expression these six kinds that are respectively as formula (1), (2), (3), (4), (5)and(6)show:

$$\sum_{i\in I} P_i \quad (1)$$

FULL PAPER

In formula(1), I is a finite set, it shows index set; Empty process is using zero to express that shows inactive process, sometimes it also uses NIL to express.

$$P_1|P_2 \quad (2)$$

In formula(2), when P_1 and P_2 can independent parallel implement, it can use formula(2)to express, and when P_2 in the port x randomly input motions, P_1 in the port x can randomly output process, in this case, it generates formula (2)dumb action.

$$\bar{y}x.P \quad y(x).P \quad or \quad \tau.P \quad (3)$$

In formula(3), y represents process one input port, $y(x)$ represents positive prefix;when in the port y randomly input name z, it can use formula $y(x).P$ to express, now it can execute $P\{z/x\}$, from which z/x represents that uses a name x to replace a name z; $\bar{y}$ represents process output port, $\bar{y}x.P$ represents a negative prefix; when in the port y randomly input name x it can use formula $\bar{y}x.P$ to express, now executes P; in the negative prefix, there is no binding name, only in the positive prefix $y(x)$, name x will be bound inside; τ represents dummy, generally process outside invisible internal action is using τ to express, $a, \bar{a}$ represents dual channel; $\tau.P$ represents after fulfilling a dumb action τ the expression of process P.

$$\mathrm{A}(y_1, y_2, ..., y_n) \quad (4)$$

In formula(4), a process identifier has unique definition, as formula (4-1)show, in(4-1)expression process P, $x_1, x_1, ..., x_n$ represent free name; process $P(y_1/x_1, ..., y_n/x_n)$ and formula(4)external behavior are the same, and in equation definition, it includes recursion, therefore process P included process is random.

$$A(x, x, ..., x) \ \underline{\underline{def}} \ P$$

$$[x = y]P \quad (5)$$

Formula(5) represents that only when $x = y$ it will execute P, otherwise execute empty process.

$$(x)P \quad (6)$$

Formula(6)represents that P is allowed to communicate by internal channel x;Due to x channel these actions communication outside expression is a dumb action, in channel x executed external action is forbidden to P.

Based on above six formulas significances, it is clear that in Pi calculus, the process can have definitions as following

$$\begin{aligned} P ::= \ & 0 \\ | \ & P_1 + P_2 \\ | \ & \bar{y}x.P \\ | \ & y(x).P \\ | \ & \tau.P \\ | \ & P_1|P_2 \\ | \ & (x)P \\ | \ & [x = y]P \\ | \ & A(y_1, ..., y_n) \end{aligned}$$

Syntax definition priority is regulated as :Restriction expression, prefix expression and matching expression are parallel ranked as premier, parallel expression is secondly priority; sum form priority is ranked as the last one.

Operational semantics

Pi calculus operational semantics are used to explain action semantics that process can execute, these action semantics not only includes process internal action, they also include interaction actions that proceeds with external process, action semantics include INPUT-ACT, TAU-ACT, OUTPUT-ACT, SUM, PAR, MATCH, OPEN, RES and COM totally nine kinds.

INPUT-ACT represents input action, when form parameter z is replaced by input y, its expression is as formula (7)show, as long as y doesn't belong to $(z)P$ free name set, y can also replace P form parameter z.

$$\frac{-}{x(z)P\underline{x(y)}P\{y/Z\}}, y \notin fn((z)P) \quad (7)$$

TAU-ACT represents empty action, after action, τ, $\tau.P$ can be converted into P, its expression is as formula (8)show:

$$\frac{-}{\tau P \underline{\tau} P} \quad (8)$$

OUTPUT-ACT represents output action, after action $\bar{x}y$, $\bar{x}yP$ can be converted into P, its expression is as formula(9)show:

$$\frac{-}{\bar{x}yP\overline{\bar{x}y}P} \quad (9)$$

SUM represents solve the sum, when process P completes operation α, it can be evolved into process P' case, then process $P+Q$ can also fulfill operation α and then is evolved into process P', the process expression is as formula (10)show:

$$\frac{P \xrightarrow{\alpha} P'}{P+Q \xrightarrow{\alpha} P'} \quad (10)$$

In formula (10)process $P+Q$ represents that chooses either P or Q to execute, therefore it can select P to execute.

PAR represents parallel, after operating α, process P can be evolved into process P', then process $P|Q$ after operating α, it can also be evolved into $P'|Q$, expression is as formula(11)show, but above parallel conclusion set up precondition is that process Q free name set doesn't include α limited name, its condition expression is as formula (12)show:

$$\frac{P \xrightarrow{\alpha} P', bn(\alpha) \cap fn(Q) = \Phi}{P|Q \xrightarrow{\alpha} P'|Q} \quad (11)$$

$$bn(\alpha) \cap fn(Q) = \Phi \quad (12)$$

MATCH represents matching, its expression is as formula (13)show :

$$\frac{P \xrightarrow{\alpha} P'}{if\ (x=y) then P \xrightarrow{\alpha} P'} \quad (13)$$

OPEN represents openness, in order to implement a limited range expanding from internal process to external process, apply limited output prefix $\bar{a}\upsilon x$, then $\bar{a}\upsilon x$ represents P one limited name x, which can transfer it through channel a to external process, above process expression is as formula (14)show:

$$\frac{P \xrightarrow{\bar{a}x} P', a \neq x}{(\upsilon x)P \xrightarrow{\bar{a}\upsilon x} P'} \quad (14)$$

RES represents restriction, expression is as formula (15)show:

$$\frac{P \xrightarrow{\alpha} P', x \notin \alpha}{(\upsilon x)P \xrightarrow{\alpha} (\upsilon x)P'} \quad (15)$$

COM represents combination, when process P can receive name x in channel a and let it to be evolved into P', and now process Q can also issue name u in the same channel and let it to be evolved into Q', then process $P|Q$ can implement synchronization action in internal process, the process is executing dummy action τ and then evolving into $P'\{u/x\}|Q'$, combination expression is as formula (16)show:

$$\frac{P \xrightarrow{a(x)} P', Q \xrightarrow{\bar{a}u} Q'}{P|Q \xrightarrow{\alpha} P'\{u/x\}|Q'} \quad (16)$$

Structure equivalence rule is as following show:

Associative law: $(P|Q)|R \equiv P|(Q|R); (P+Q)+R \equiv P+(Q+R)$

Commutative law: $P+Q \equiv Q+P; P|Q \equiv Q|P$

PI CALCULUS MODELING-BASED WEB SERVICE

If in Web service combination design stage, it omits combination process validation, then it is prone to generate lots of mistakes when combination is running, therefore firstly apply validation technology to test and make design error repairing on Web service combination in design stage, meanwhile carry out demand compliance validation on service flow by applying formalization method, and then run it. Services that participate in combination include complicated operations, therefore it is necessary to execute according to certain rules, and however for presently semantic service com-

FULL PAPER

bination language that lacks of formalization, generally these formalization semantics cannot use their own languages to establish models and analyze and verify the model, and also cannot model for communication and concurrence. Based on Web combination service, apply Pi calculus formalization description to express Web service combination, and then make corresponding on the two basic elements one by one, complete Pi calculus essential conditions in Web service combination modeling.

Correspondence

Pi calculus basic elements and Microsoft Biztalk applying XLANG language involved Web service elements correspondence is as Figure 3 show.

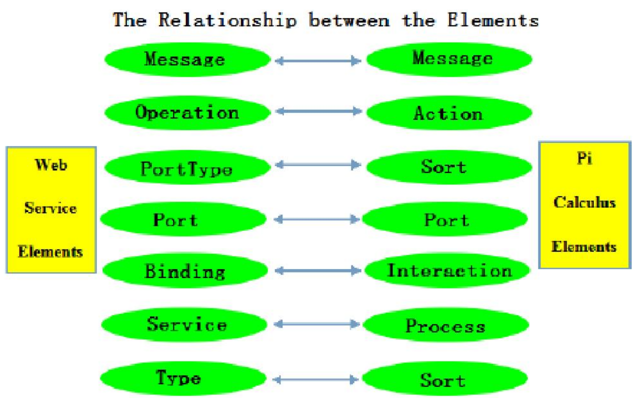


Figure 3 : Elements one-to-one correspondence figure

Pi calculus –based Web service combination is applying flow description method to describe Web service, use Pi calculus process to express Web services. Due to Pi calculus jointly calls entity as name, so it can correspond its process into value. Pi calculus flow is as Figure 4 show.

In Figure 4, P, Q represents process that can issue and receive information along channel, (y) represents receiving information, '$\langle y \rangle$ represents output information, in Web service, services correspond to Pi calculus process, then its corresponding syntax is as following definitions:

['x<a>.P] represents a outputs along channel x, and then executes P;

[x(b).P] represents b inputs along channel x, and then executes P;

[P1+P2] represents that selects to execute P1or P2;

[P1%P2] represents that concurrent executes P1andP2;

[P1.P2] represents successively executes P1, P2 according to order;

[!P] represents infinitely copies P, and concurrent executes;

[[condition]P] represents only when condition is in the state true, it can execute P

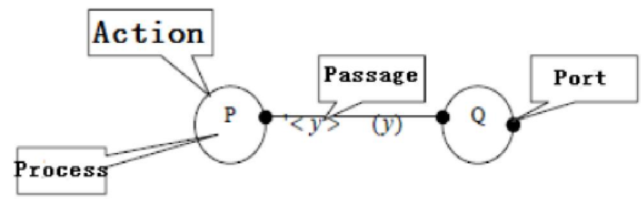


Figure 4 : Pi calculus flow

Service Pi calculus description

Assume a compound travel plan service flow, it s plan system figure and corresponding Pi calculus system figure is as Figure 5 show.

As Figure 5, composite service totally involves 9 pieces atomic Web services as TABLE 1 show.

Use Pi calculus formalization Figure 5 system information, adopt four composite services to represent client agent, inquiry time agent, transportation agent and hotel agent, and take the four services as Pi calculus Client, Time, Transportation and Hotel four processes.

tr: Client sends two places inquiry time request to time;

t:Time returns to Client time;

tri: Transportation returns to Time, Time selected transportation information when returns to Client;

hi: Hotel returns to Time, and then Time returns to Client hotel information where is planning to go:

bt: Client released booking information to Transportation;

bh: Client released hotel booking information to Hotel;

n: In case no tickets, Transportation feedback information to Client;

ot: Return to booking information;

oh: Booked hotel information.

Description about service Client Pi calculus is as following Figure show:

Client(x,u,tr,t,tri,hi,w,bt,bh,n,oh,ot,hi,message)= 'x<tr>.x(t,tri,hi). 'w<bt>.w(message).('u<bh>.u(oh).Client<x,w,u,tr,t,tri,bt,bh,n,oh,ot,hi,message>+[mssage=n] Client(x,w,u,tr,t,tri,bt,bh,n,oh,ot,hi,message))

Description about service Time Pi calculus is as following Figure show:

Time(x,y,z,tr,t,tri,hi)=x(tr).y(tri).z(hi). 'x<t, tri, hi>.Time(x,y,z,tr,t,tri,hi)

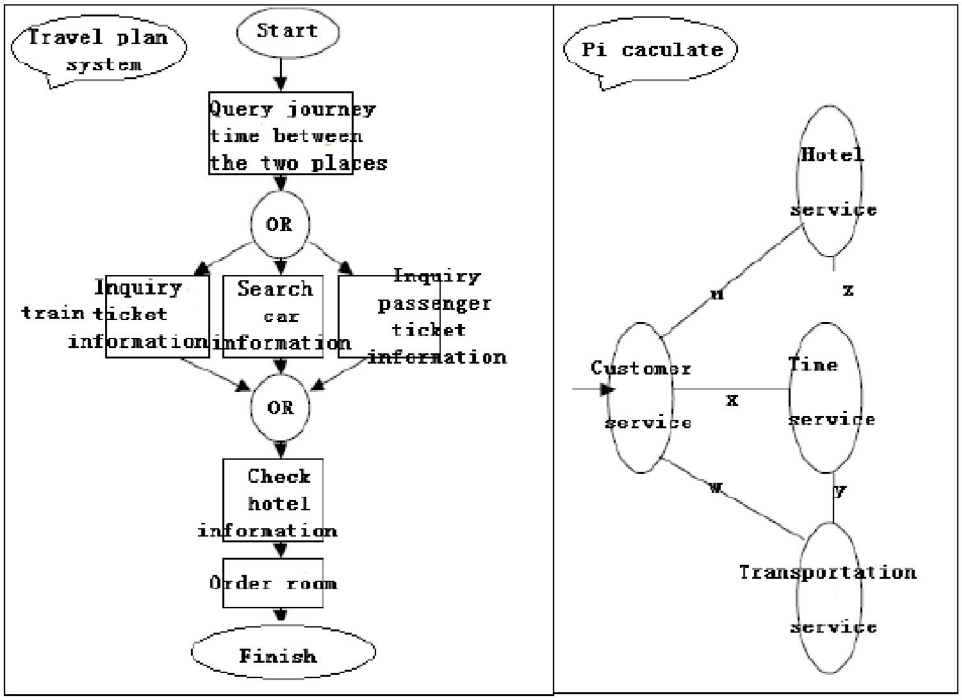


Figure 5 : Travel plan system figure

TABLE 1 : Composite service involved nine pieces of atomic Web services

No.	Symbol	Explanation
1	GetDriveTme (A, B)	Inquire A-B driving time
2	getFlightInfo (A, B)	Inquire A-B flight and then return to flight information
3	BookAirline (C, FNo, Date)	Book C airline the data as Date flight number as FNo air ticket
4	getTrainInfo(A, B)	Inquire A-B train number and then return to train number information
5	BookTrain (TNo, Date)	Book data is Date, train number is TNo train ticket
6	GetCarInfo (A)	Inquire place A car rent information and then return to inquiry information
7	BookCar (CNo, Date1, Date2)	Book time is Date1-Date2, car number is CNo car
8	GetHotelInfo (B)	Inquire place B hotel and then return to inquiry information
9	BookHotel (H, Date1, Date2)	Book H hotel, time as Date1-Date2 one room

Description about service Transportation Pi calculus is as following Figure show:

Transportation(y,w,tri,bt,n)='y<tri>.w(bt).('w<n>.Transportation (y,w,tri,bt,n)+ 'w<ot>.Transportation(y,w,tri,bt,n))

Description about service Hotel Pi calculus is as following Figure show:

Hotel (z,u,oh,bh,hi) ='z<hi>.u (bh).'u<oh>.Hotel (z,u,oh,bh,hi)

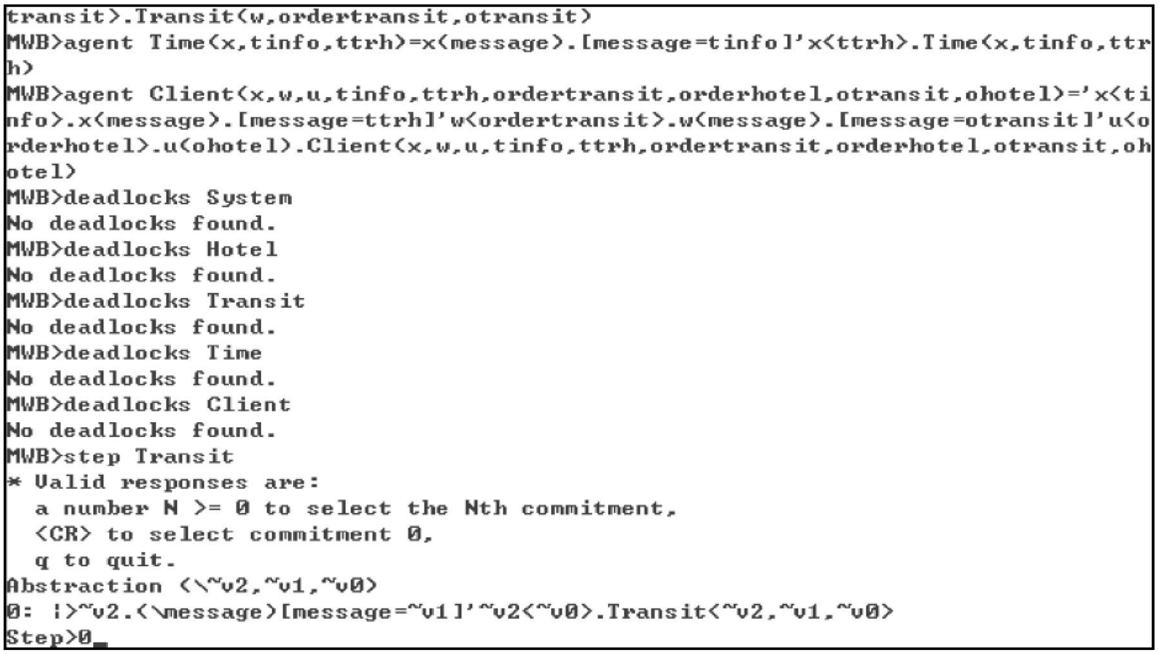
Based on above four sub services Pi calculus description, then the whole travel plan processing service, OWL-S uses Pi calculus to express is as following Figure show :

System=Client(x,w,u,tr,t,tri,bt,bh,n,oh,ot,hi,message)|Time(x,y,z,tr,t,tri,hi)|Transportation(y,w,tri,bt,n)|Hotel(z,u,oh,bh,hi)

PI CALCULUS VALIDATION

Pi calculus validation tool includes Another Bissimulation Checker that is called ABC for short, History-dependent Analysis Laboratory that is called HAL for short, Just Another Concurrent Kit that is called JACK for short and the Mobility Work Bench that is called MWB for short as well as other tools, the paper adopts MWB tool to analyze operational mobile concurrent system automatic Pi calculus. Its experiment result is as Figure 5 show.

By Figure 5 validation result, it shows that plan system doesn't exist structural deadlock situations, the



```
transit>.Transit<w,ordertransit,otransit>
MWB>agent Time<x,tinfo,ttrh>=x(message).[message=tinfo]'x<ttrh>.Time<x,tinfo,ttr
h>
MWB>agent Client<x,w,u,tinfo,ttrh,ordertransit,orderhotel,otransit,ohotel>='x<ti
nfo>.x(message).[message=ttrh]'w<ordertransit>.w(message).[message=otransit]'u<o
rderhotel>.u(ohotel).Client<x,w,u,tinfo,ttrh,ordertransit,orderhotel,otransit,oh
otel>
MWB>deadlocks System
No deadlocks found.
MWB>deadlocks Hotel
No deadlocks found.
MWB>deadlocks Transit
No deadlocks found.
MWB>deadlocks Time
No deadlocks found.
MWB>deadlocks Client
No deadlocks found.
MWB>step Transit
* Valid responses are:
  a number N >= 0 to select the Nth commitment,
  <CR> to select commitment 0,
  q to quit.
Abstraction (\~v2,~v1,~v0)
0: |>~v2.(\message)[message=~v1]'~v2<~v0>.Transit<~v2,~v1,~v0>
Step>0_
```

Figure 5 : MWB proof result figure

whole service combination process is fully correct, verify and get the whole system intactness and reliability, therefore it is clear in Pi calculus description normalization and inference mechanism, formalization description is fit for semantic Web service modeling, and when use special validation tool, the dynamic process is relatively easier to observe and is direct.

CONCLUSION

Process algebra not only has advantage as strong expressive ability, but also its form is relative more concise; Pi calculus-based semantic Web service combination formalization and its validation method provide better theoretical basis for Web service combination; Formalization method has serious inference mechanism, Pi calculus meanwhile has serious description normalization, which provides theoretical basis for Web service combination better development.

ACKNOWLEDGMENT

This work is supported by Fund of Hunan Provincial Education Department of China (09C887).

REFERENCES

[1] Du Li-Feng, Niu Yong-Jie; Implementation of ant colony algorithm in MATLAB. Information Technology, **6**, 115-118 **(2011)**.

[2] Wu Qing-Hong, Zhang Ji-Hui, Xu Xin-He; An ant colony algorithm with mutation features. Journal of Computer Research and Development, **36(10)**, 1240-1245 **(1999)**.

[3] Ma Xiao-Li, Cai Xiu-Feng, Zhao Zhan-Fang, Wano Nan; Comparison and Parameter Optimization of Ant Colony System. Digital Community & Smart Home, **3**, 1324-1325 **(2007)**.

[4] Yan Chen Yang, Zhang You Peng, Xiong Wei Qing; Analysis on Performance of Novel Pheromone Trails Update Strategy in Ant Colony Optimization. Application Research of Computers, **24(7)**, 86-88 **(2007)**.

[5] Ji Yaofeng, Dang Pei, Guo Xiaobo; Study of Job Shop Scheduling Problem Based on an Improved Ant Colony Algorithm. Computer and Digital Engineering, **39(1)**, 4-6, 52 **(2011)**.

[6] Zhu Kaiyan, Cheng Xuxiao; Dual Population Ant Colony Optimization Based on Pheromone Diffusion. Microcomputer Applications, **31(7)**, **(2010)**.

[7] Luo Jia-Wei, Chen Fei, Peng Dong-Hai; Hybrid behavior based ant colony pairwise alignment method. Computer Engineering and Applications, **45(11)**, 150-153 **(2009)**.

[8] Wan Bo, Lu Yu, Chen Liyun, He Ruibo; Optimization for Multiple Constraints Transportation Path Based on Mutated Ant Colony Algorithm. Microcomputer Applications, **32(7)**, 6-12 **(2011)**.