

## Robot Multi-Tasks Optimization Using Improved JSHOP2 Planner

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### Abstract

*It has been shown in recent research that integrating the JSHOP2 planner with service robot task planning is appropriate and efficient. However, only few researches demonstrate the application of JSHOP2 planner in the problem of multi-tasks planning. The main reason is the environment that a service robot acts in is complex and the existing JSHOP2 planner is unable to adjust tasks' order. To solve this issue, in this paper, an improved JSHOP2 planner integrated with robot task planning is built. To make the tasks execution sequence more acceptable to users, different priorities are assigned to all the service tasks through comparing the characteristics of the tasks. According to the priority, the improved JSHOP2 planner is built. The simulation results show that the improved JSHOP2 planner is feasible and can improve the intelligence of service robot task planning.*

**Keywords:** JSHOP2 planner, service robot, multi-tasks optimization, task priority

### 1. Introduction

In recent years, with the development of robotic technology, service robot has gradually entered home, office and other places for providing services to human and become a novel tool to improve the quality of human life. Task planning is an important research field of robotics and also an interesting integration point of artificial intelligence with robotics. Service robot task planning problem oriented to service tasks has aroused wide concerns of scholars. Many scholars have carried extensive research on this issue [1-4]. Yuchul Jung et al. proposed a cognitive case-based planning framework for home service robot. With the help of human interaction, the framework can achieve task planning through retrieving case base [5]. Yong-Hwi Kim et al. introduced a multi-robots task planning system for hospital service and aimed at minimizing the total execution time [6]. Marcello Cirillo et al. built a human-aware planner, which can instruct mobile robots to perform tasks [7]. Yi Zeng et al. proposed a memory-based mechanism for robot task and motion planning [8-9]. In literature [8], they integrated the SHOP2 planner in their control architecture as the deliberative planner. To get the lacking information for robot planning, they combined a robotics memory base and probability inference. Their methods can realize the dynamic planning and execution of a service task. But in the above researches, the main works were focused on executing one task at a time and make an effort to improve the performance on robot system itself. However, when there are multi-tasks which are requested by users, service robot should have the ability to determine the efficient tasks sequence to be satisfied by users as well as by robot itself. To make people's lives more comfortable and enjoyable, user's satisfaction need to be considered as an important factor of task planning.

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JSHOP2 is a domain-independent HTN planning system. It has been widely used in many fields, such as automatic service composition, distributed planning, Multiple UAVs controlling and so on [10]. JSHOP2 can perform simple task planning, but it is difficult for the existing JSHOP2 planner to meet the requirements of home service task planning because it is unable to optimize multi-tasks sequence. In home environment, a service robot which can plan multi-tasks should deal with many constraints, such as user's satisfaction, user's needs level, task's characteristics and so on. According to these constraints, the sequence of service tasks requested from users must be adjusted. Such adjustment will not only allow the robot to produce solutions more properly but also make the solutions more likely to be acceptable to users.

In order to solve the problem of multi-tasks planning, an improved JSHOP2 planner is built in this paper. Firstly, different priorities are assigned to all the service tasks in home service environment through comparing the characteristics of tasks and considering the service needs level of users, then the optimization of tasks' execution order based on priority level can be realized by modifying the source code of JSHOP2 planner. The simulation results show that the improved JSHOP2 planner is feasible.

## 2. JSHOP2 Planner Integrated with Robot Task Planning

JSHOP2 planner is a Java implementation of SHOP2 planner. As other HTN planners, SHOP2 searches top-down from a task or set of tasks [11-12]. The objective of SHOP2 planner is to produce a sequence of actions that perform some activity or task. JSHOP2 records *methods* and *operators* of specific domain into planning domain file. Each *method* indicates how to decompose a compound task into a partially ordered set of subtasks, which can be compound or primitive. Each *operator* indicates how a primitive task can be performed. Given a planning domain, the description of a planning problem will contain an initial state and a partially ordered set of tasks to accomplish. In contrast to the domain description, the problem description changes whenever the situation changes and whenever the system is confronted with new tasks.

JSHOP2 planner integrated with robot planning can achieve not only a single task planning, but also multi-tasks planning. When performing multi-tasks planning, task list may be constrained to be “:ordered”, or can be executed in any order (declared by “:unordered”). In the JSHOP2 formalism, multi-tasks can be described as follows:

1) (:ordered (send\_water person1) (cleanhouse house))

The above rule indicates that two tasks are requested, one is “send\_water”, and the other is “cleanhouse”. The “:ordered” keyword means that JSHOP2 must perform the task list in the order that they are given. So the planning and execution order must be firstly “send\_water”, and then “cleanhouse”. This approach is suitable for the fixed tasks' planning in constant environment, but not for the robot task planning under home environment.

2) (:unordered (send\_water person1) (cleanhouse house))

As is shown in the above request, the “:unordered” keyword specifies that there is no particular ordering specified between “send\_water” and “cleanhouse”. With the use of the “:unordered” keyword, JSHOP2 may interleave tasks between different task lists. This approach increases the adaptability of tasks.

3) On the premise of declared by “:unordered” keyword, the task list can be requested as follows:

(:unordered (send\_water person1) (:immediate open\_TV TV))

Note that a task with the “:immediate” keyword specifies that this task must be performed immediately when it has no predecessors. Therefore, we can allow only one task with the “:immediate” keyword in the list of tasks that have no predecessors at any given point during the planning process. In the above requested task, the second task “open\_TV” is declared by “:immediate” keyword. So JSHOP2 planner will give first

priority to execute “open\_TV”, and then execute “send\_water”. This approach can achieve prior execution of certain task, such as emergency task. But the shortcoming is that this method can only give “:immediate” to one task. When three or more tasks are requested, this method is unable to sort the execution order of all the tasks.

JSHOP2 can do simple multi-tasks planning, but it is difficult for the existing JSHOP2 planner to meet the requirements of home service task planning because it is unable to optimize the execution sequence of all the requested tasks.

### 3. Multi-Tasks Optimization Using Improved JSHOP2 Planner

#### 3.1. Problem Description

The complexity and diversity of the current robot tasks in home service environment increase the difficulty in the planning of multi-tasks. The tasks may be daily tasks, real-time tasks or emergencies. So a service robot must be able to plan a series of tasks at a time. As the service target is “people”, the service robot must have the ability to provide efficient services and emergency response through imitating human’s brain. Planning process should consider not only the task execution performance of robot itself, but also the satisfaction of users.

In multi-tasks situation, in order to measure the effectiveness of a plan, a new concept named the comprehensive effects of task execution is proposed in this paper. The comprehensive effects of task execution means the factors of users should be considered during task execution; that is a robot should adjust task’s execution order based on user’s needs level, and with the objective to decrease user’s waiting time and improve user’s satisfaction.

Consider the following question: At a certain time robot receives  $m$  home service tasks  $T_1, T_2 \dots T_m$ . Each task is described by a two-tuples  $T_i(p_i, t_i)$ .  $p_i$  represents the task category, include emergency tasks, real-time tasks and daily tasks;  $t_i$  represents the task execution time.

To achieve the best comprehensive effects of task execution, the main work of multi-tasks planning problem is considering the characteristics of each task  $T_i(p_i, t_i)$  and optimizing the execution order of tasks  $T_1, T_2 \dots T_m$ .

#### 3.2. Task Priority Assignment

Currently, priority determining methods are earliest deadline first (EDF) and earliest request first (ERF) [13-14]. Task priority may be determined by one or more characteristic parameters, such as deadline, idle time and critical (importance of the task). But due to the diversity, complexity and dynamic characteristic of robot service tasks in home environment, the deadline and idle time of the robot tasks are uncertain. Therefore, traditional priority determining method is not suitable for the home services robot tasks. To solve this problem, in this paper, service tasks are classified according to the tasks’ characteristics, and then different priorities are assigned to the tasks combined with task’s execution time.

Because of the limited number of robot service tasks in home environment, it is feasible for this paper to classify all the tasks and assign priority. Several elements are chosen to determine task priority, such as user’s needs level, user’s waiting time, user’s satisfaction and the characteristics of home service tasks. Based on these elements, home service tasks are divided into three categories: emergency tasks, real-time tasks and daily tasks. Table 1 lists the classification, priority and the execution time of these tasks. In Table 1, emergency tasks including *fall*, *help*, they have the highest priority, because all of these tasks are urgent and have high user’s needs level. If there is nothing for first consideration, real-time tasks including *send water*, *open curtain*, *open TV* and so on will be selected as the first. Daily tasks, such as *clean house*, have the lowest priority. This is

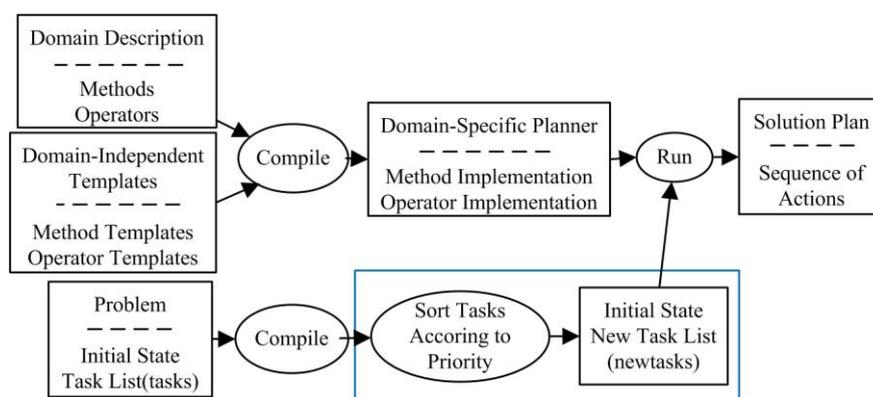
because daily tasks are usually set in advance to complete every day and the user's needs level to these tasks is not high, so robot may complete these tasks at spare time. But if several tasks in same category are requested, they will be ordered according to the execution time of the tasks. For example, in real-time tasks category, the execution time of *open TV*, *open curtain* and *send water* are 1, 2, 3(in minutes), respectively. The priority of the three tasks that sorting in descending order is *open TV*, *open curtain* and *send water*. If several tasks in same category have the same execution time, the priority of these tasks will be determined by JSHOP2 planner based on the current state information.

**Table 1. Classification and Priority Of Service Tasks**

Category and Priority	Task Name	Task Execution Time(Minute)
1 <sup>st</sup> : Emergency Tasks	Fall(emergency_fall)	5
	Help(emergency_help)	10
2 <sup>nd</sup> : Real-time Tasks	Open TV(open_TV)	1
	Open Curtain(open_curtain)	2
	Send Water(send_water)	3
3 <sup>rd</sup> : Daily Tasks	Clean	60
	House(cleanhouse)	

### 3.3. Improved JSHOP2 Planner Principle

After determining the priority of tasks, the process of automatically optimizing the tasks' execution order based on task priority can be realized through modifying the source code of JSHOP2 planner. The source code of JSHOP2 planner is written in Java language. Figure 1 shows the compilation processes of JSHOP2. A unique feature of the JSHOP2 planner is a two-fold compilation and planning process. JSHOP2 is a compiler of its domain description, meaning that it compiles a given domain description to a domain-specific planner, and then runs that planner to solve the planning problems in that domain. Similarly, JSHOP2 compiles problem description which records requested tasks and environmental states to problem-specific description of Java format. So, as is shown in the blue box of Figure 1, the process of optimizing tasks' execution order should be implemented after the compilation processes of problem description.



**Figure 1. Compilation Processes Of JSHOP2**

Two properties, *taskName* and *taskPriority*, are added to the requested task list tasks to store task's name and task's priority, respectively. Figure 2 shows the code of changing task order. Since in JSHOP2 source code the name of methods and operators is stored through index, the code shown in Figure 2 firstly obtains *taskName* through task's index,

and then passes *taskName* as argument to *getTaskPriority* function to assign priority to every task. Finally, an improved task list *newTasks* will be generated through *changeOrder* function using *taskPriority* as argument.

```

changeTaskOrder
Input:tasks
Output:newTasks

Begin
For(int i=0;i<tasks.subtasks.length;i++)
{
index=getTaskIndex(tasks.subtasks[i]);
tasks.subtasks[i].taskName=getcompoundTasks(index);
tasks.subtasks[i].taskPriority=getTaskPriority(tasks.subtasks[i].taskName);
}
newTasks=changeOrder(tasks.subtasks.taskName,tasks.subtasks.taskPriority);
End

```

**Figure 2. Code of Changing Task Order**

```

improvedJSHOP2
Input:domain file,problem,file
Output:plan

Begin
tasks=JSHOP2.InternalDomain(domain file,problem,file);
newTasks=changeTaskOrder(tasks);
plan=findFlan(newTasks);
JSHOP2GUI(plan);
End

```

**Figure 3. Main code of the improved JSHOP2**

After re-sorting the order of original task list, through passing the *newTasks* as argument to *findFlan* function of JSHOP2 planner, a plan list *plan* will be generated. The *JSHOP2GUI (plan)* statement is used to display the generated plan list on graphical user interface. The main code of this process is shown in Figure 3.

#### 4. Simulations and Results

To verify the effectiveness of the improved JSHOP2 planner, simulation experiments were conducted and the results were compared with original JSHOP2 planner. In each experiment, four tasks including *clean house*, *send water*, *open TV* and *fall* were requested. However, the format of the requested task list in the original JSHOP2 planner and the improved JSHOP2 planner was different:

1) Original JSHOP2 planner can give a higher priority to one task by adding “:immediate” keyword to the requested task list. Requested task list was shown as follows:

*(:unordered (cleanhouse house)(send\_water person1)(open\_tv tv)(:immediate emergency\_fall person2))*

2) The improved JSHOP2 planner can assign priority to every task without adding any keyword. Requested task list was shown as follows:

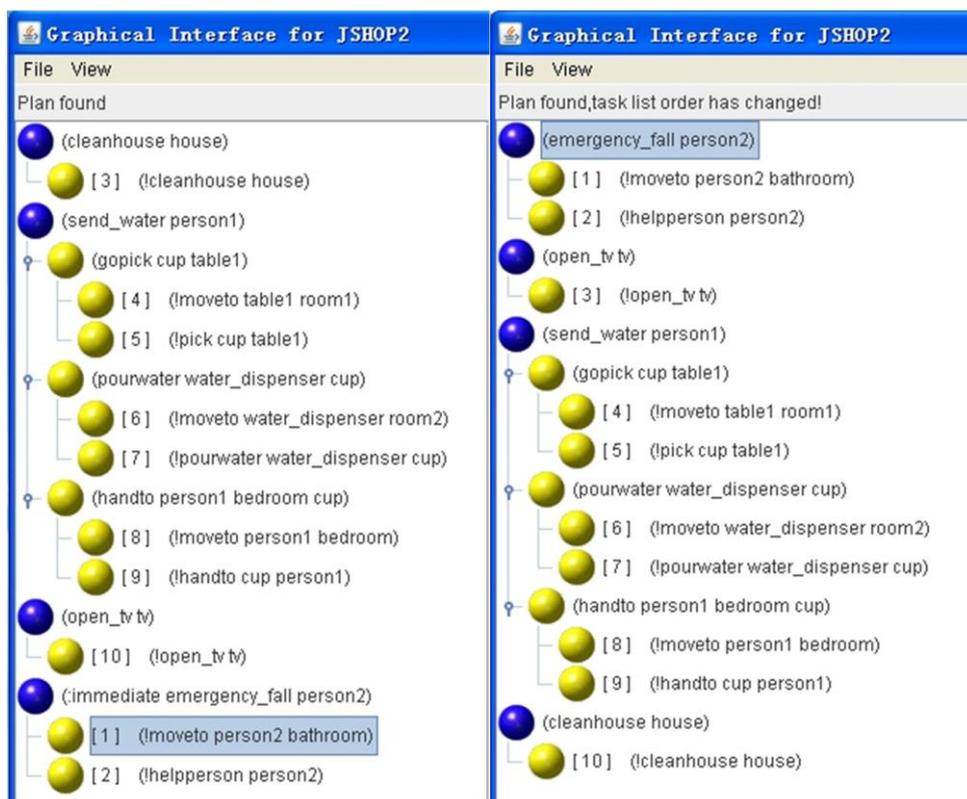
*(:unordered (cleanhouse house)(send\_water person1)(open\_tv tv)(emergency\_fall person2))*

The simulation results of the above two task lists were shown in Figure 4. Figure 4(a) shows the plan list generated by original JSHOP2 planner and Figure 4(b) shows the plan list generated by improved JSHOP2 planner. The purple ball in Figure 4 represents the requested tasks, and the yellow ball represents robot actions. The number in square

bracket in front of robot action indicates the execution sequence of the robot action. The process of generating a plan in our improved JSHOP2 planner took less than 10ms.

In Figure 4(a), original JSHOP2 planner realized the first execution of the (:immediate emergency\_fall person2) task which has been declared by “:immediate” keyword, then followed in sequence by the execution of (cleanhouse house), (send\_water person1) and (open\_tv tv). The execution order of the last three tasks was the same as the request order, suggesting that original JSHOP2 planner did not realize the optimization of the three tasks. As described in the above section, the (cleanhouse house) task belongs to daily task, while (send\_water person1) and (open\_tv tv) belongs to real-time task. User’s needs level to (send\_water person1) and (open\_tv tv) is apparently higher than (cleanhouse house). So the plan in Figure 4(a) increased user’s waiting time on (send\_water person1) and (open\_tv tv), resulting in a poor comprehensive effects of task execution and declining user’s satisfaction.

Figure 4(b) shows that the improved JSHOP2 planner adjusted the order of original task list. With the adjustment, the first task to be executed was (emergency\_fall person2) task which had been assigned top priority. And followed in sequence by the execution of (open\_tv tv) and (send\_water person1), both of the two tasks were real-time task and assigned second priority. The (cleanhouse house) task which belongs to daily task was the last to be executed. Thus decreased user’s waiting time on (send\_water person1) and (open\_tv tv), and increased the comprehensive effects of task execution and user’s satisfaction compared with Figure 4(a).



(a) The simulation result of original JSHOP2 planner

(b) The simulation result of improved JSHOP2 planner

**Figure 4. Simulation Results**

Through comparing the simulation results of the original JSHOP2 planner and the improved JSHOP2 planner, we conclude that the improved JSHOP2 planner can adjust

task order and generate a proper plan list, achieving the purpose of optimization of multi-tasks.

## 5. Conclusion

This paper builds an improved JSHOP2 planner to realize robot multi-tasks optimization in home environment. First all the service tasks are classified and assigned priority through comparing the characteristics of the tasks and considering the service needs level of users. Then the optimization of tasks according to priority level can be realized by building the improved JSHOP2 planner. The simulation results show that compared with original JSHOP2 planner, our improved JSHOP2 planner can realize multi-tasks optimization and generate plans that are more likely to be satisfied by users. However, the existing solutions cannot realize dynamic robot task planning. The key improvement point in future work is to realize the dynamic planning of the JSHOP2 planner.

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