Value-based Multiple Software Projects Scheduling with Genetic Algorithm

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Agenda

- Introduction
- Motivating Example
- Value Function for Multi-project Scheduling
- Multi-project Scheduling with Genetic Algorithm (GA)
- Case study
- Conclusions and Future Work

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Background

- Multi-project environment
  - Contention resource requirements among multiple projects
  - The projects may have different stakeholders who bear different requirements and preferences
  - Each project holds different constraints and different value objectives
- One of the goals of an organization
  - Achieve the maximum value from the projects and response to the changing market timely

Problems in multi-project scheduling

- Define the value obtained by scheduling according to constraints, value objectives and possible scheduling results in projects
- Provide a multi-project scheduling method which can obtain the (near-) maximum value for the organization

Need decision support to managers

Related Work

- Multi-objective release planning
- Simulation method
- Project portfolio management
- Resource scheduling in software projects

Our Method

- Value-based multiple software projects scheduling method by using a genetic algorithm
  - Value function in multi-project environments is defined to guide the scheduling
  - Genetic algorithm (GA) is adopted to tackle the problem of high complexity and can help the scheduling get nearly optimal solutions with high efficiency

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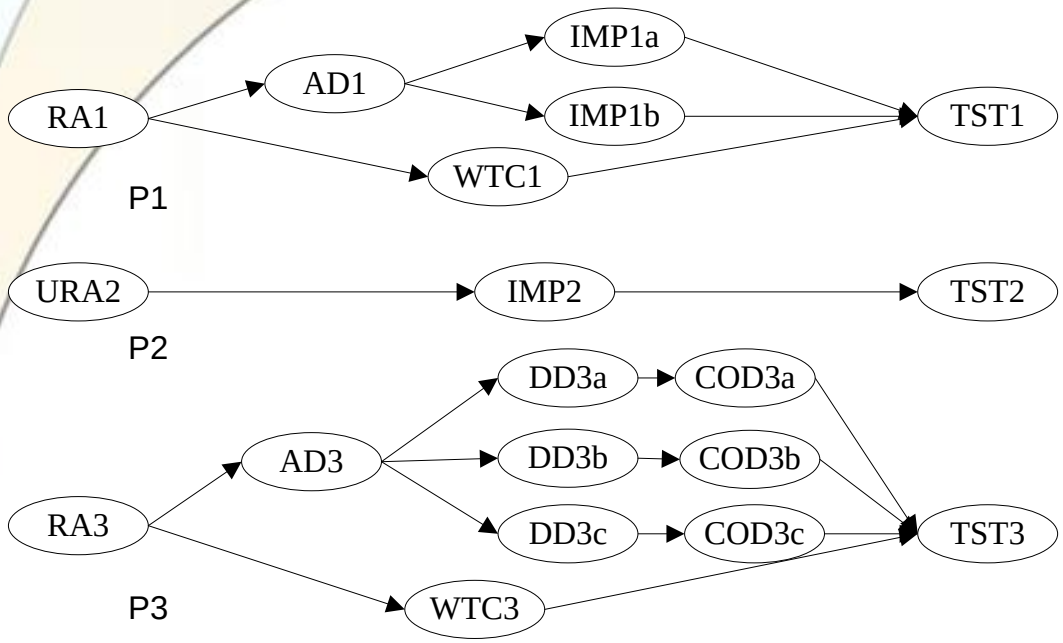

Annotations:
RA – Requirement Analysis;
AD – Architecture Design;
IMP – Implementation;
WTC – Write Test Case;
TST – Testing;
URA – Upgrading Requirement Analysis;
DD – Detailed Design;
COD - Coding

- Benefit
  - Increase in customer satisfaction
  - More money earned by the organization
- Penalty
  - Compensation asked for by the customer
  - Decrease in customer satisfaction

	P1	P2	P3
Schedule constraint	[2008-03-01, 2008-07-20]	[2008-04-10, 2008-6-30]	[2008-03-01, 2008-10-31]
Cost constraint	$2*10^5$	$5*10^4$	$3.5*10^5$
Preference	Cost preference	Schedule preference	Cost preference
Schedule ahead benefit ($/day)	400	500	500
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Cost saved benefit ($)	Equal to saved	Equal to saved	Equal to saved
Cost exceeded penalty ($)	Equal to exceeded	Equal to exceeded	Equal to exceeded
Project failure penalty($)	10^6	10^6	10^6
Project importance preference	4	1	2

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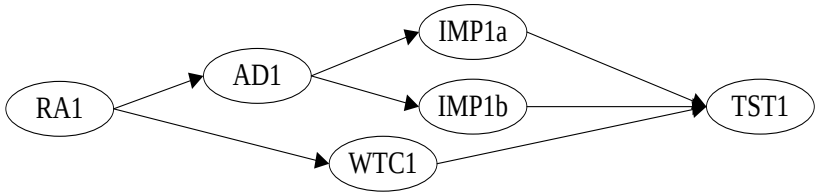
Description of Projects

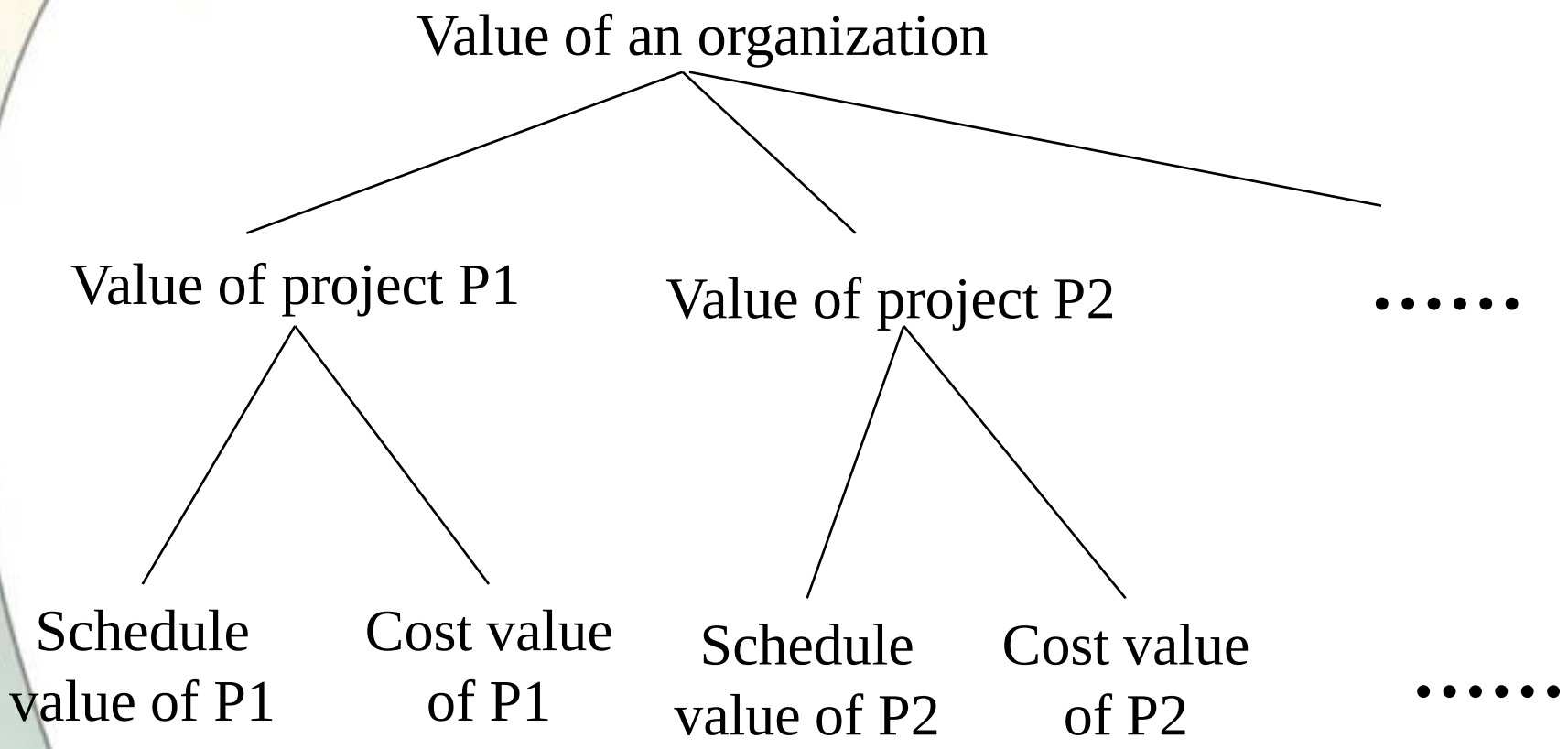
- $P_i = (ActSet_i, ConSet_i, PWSet_i)$
  - Activity Set: Each activity is described by the attributes including identification (ID), type (TYPE), size (SIZE), and required skills for human resources (SKLR)
  - Constraint Set
    - schedule constraint: [SD, DD]
    - cost constraint
  - Preference Weight Set
    - preference weight of the project (PPW)
    - preference weight of the schedule (SPW) and the cost (CPW)



Description of Human Resources

- identification (ID)
- executable activity type set (EATS)
- skill set (SKLS)
- experience data (EXPD)
- salary per man-hour (SALR)
- schedulable time and workload (STMW)

Multi-project Value Function



Multi-project Value Function

- Project Schedule Value (SValue)

$$SBenefit_i = CSB_i * \frac{|DD_i - AFD_i| + (DD_i - AFD_i)}{2}$$

$$SPenalty_i = CSP_i * \frac{|AFD_i - DD_i| + (AFD_i - DD_i)}{2}$$

$$SValue_i = SBenefit_i - SPenalty_i$$

Multi-project Value Function

- Project Cost Value (CValue)

$$CBenefit_i = CCB_i * \frac{|CST_i - APrjCST_i| + (CST_i - APrjCST_i)}{2}$$

$$CPenalty_i = CCP_i * \frac{|APrjCST_i - CST_i| + (APrjCST_i - CST_i)}{2}$$

$$CValue_i = CBenefit_i - CPenalty_i$$

Multi-project Value Function

- Project *Pi*

$$Value_i = SPW_i * (SBenefit_i - SPenalty_i) + CPW_i * (CBenefit_i - CPenalty_i)$$

- Organization

$$Value_{multi} = \sum_{i=1}^{k} (PPW_i * Value_i)$$

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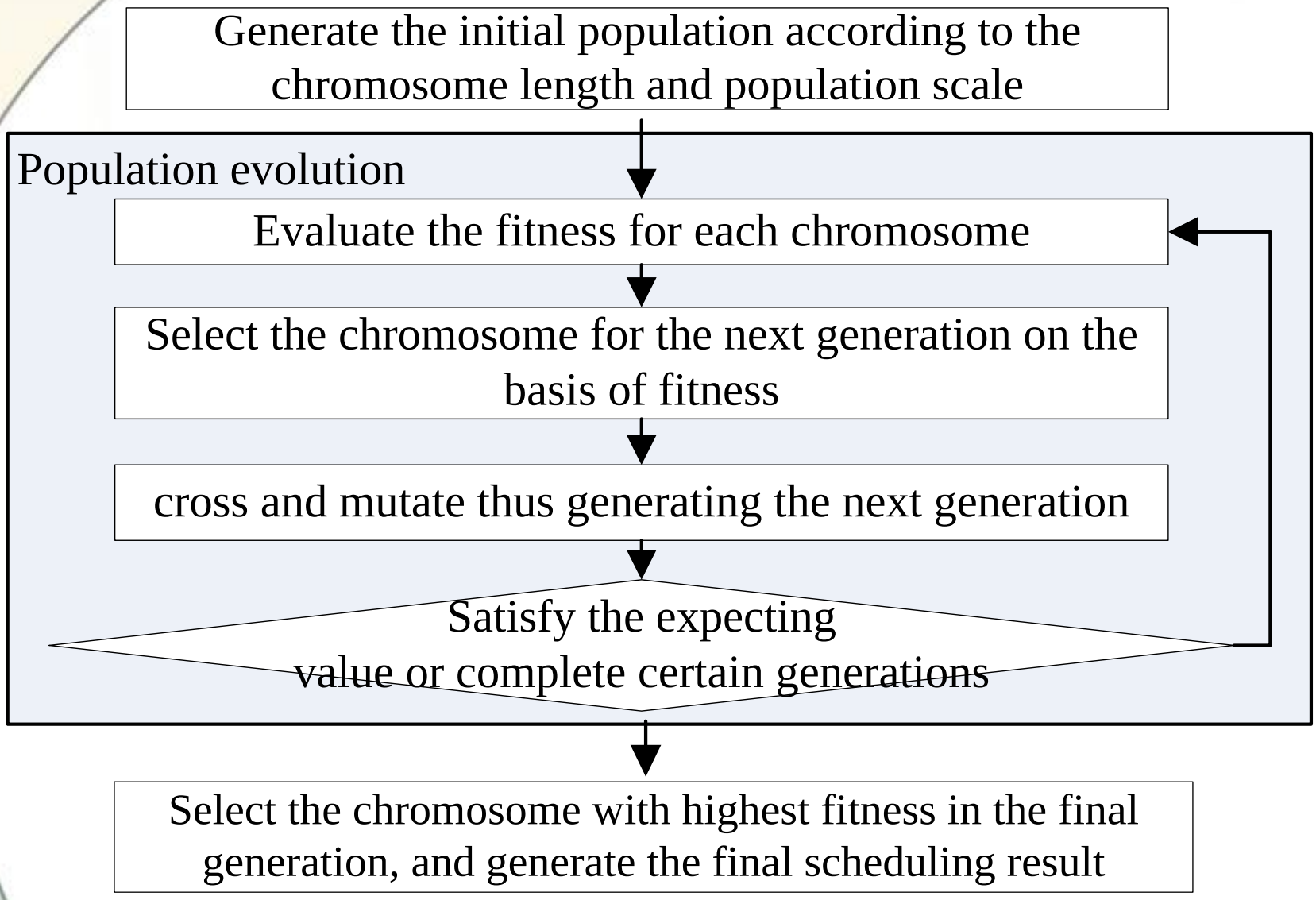
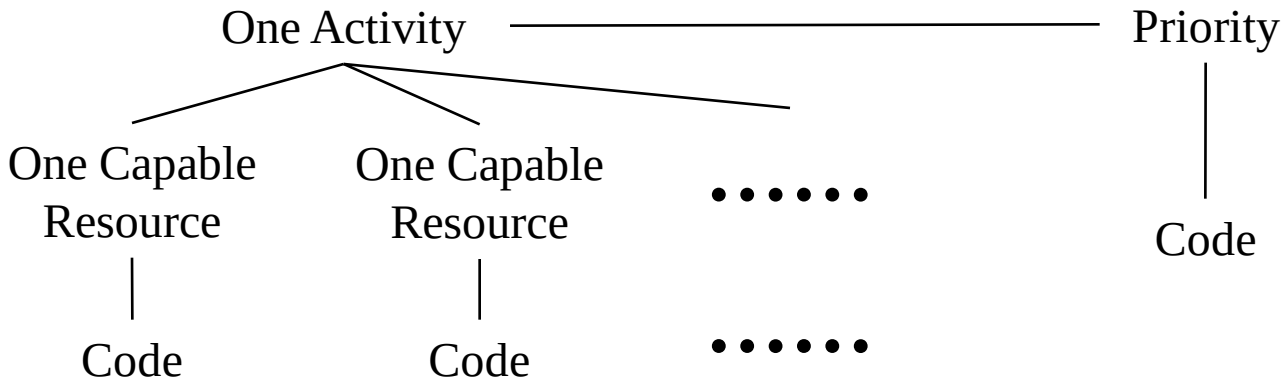
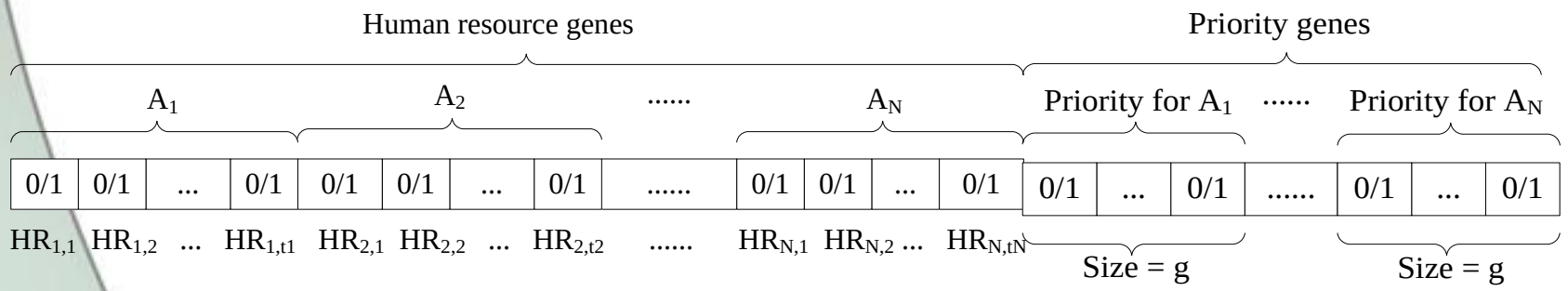

Generate the initial population according to the chromosome length and population scale
Population evolution
Evaluate the fitness for each chromosome
Select the chromosome for the next generation on the basis of fitness
cross and mutate thus generating the next generation
Satisfy the expecting value or complete certain generations
Select the chromosome with highest fitness in the final generation, and generate the final scheduling result

Structure of the Chromosome

- Encode

  A1, A2, ……, AN





Structure of the Chromosome

- Decode
  - (1) Select all the activities that do not have precedent activities or whose precedent activities have been assigned. If no such activity exists, then decoding is completed.
  - (2) Sort all selected activities as a queue according to their priority from high to low.
  - (3) For each activity "*ACT*" in this queue, do the following steps:
    - a) Set the capable human resources whose corresponding gene value is "1" as the scheduled human resources for *ACT*.
    - b) Set the start date of *ACT* as the current date.
    - c) Allocate all the schedulable workload of all the scheduled human resources in the current date to *ACT* and update the availability state of the resources.
    - d) If the scheduled workload to *ACT* can complete *ACT*, then set current date be the due date of *ACT* and update the start date of the activities whose precedent activity is *ACT* as the current date. Go to (3).
    - e) Add one day to the current date, go to (c).
  - (4) Go to (1).

Fitness Function of the Chromosome

$$Fitness = \begin{cases} (Value_{multi})^2 & \text{if} \quad Value_{multi} > 1 \\ 1 & \text{if} \quad Value_{multi} \in [-1,1] \\ \left(1 / -Value_{multi}\right)^2 & \text{if} \quad Value_{multi} < -1 \end{cases}$$

Running the Genetic Algorithm

- Set the parameters for running the GA
  - Population scale (PS): the number of the chromosomes.
  - Mutation rate (MR): the possibility of mutation to chromosome.
  - Maximum generation number: the largest number of generations.
  - Termination condition: when the running of the GA should be terminated.
- After parameter setting, the scheduling will be performed according to GA steps.

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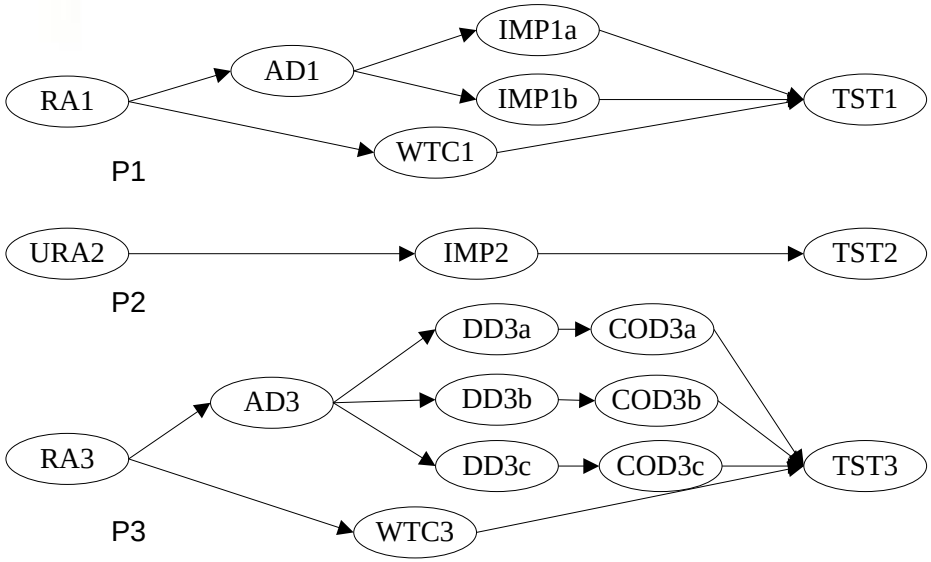
Projects and Human Resources



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- 22 human resources
- Each human resource has stable productivity in each of the executable activity types.

	EATS	EXPD(KLOC/Man-Hour)	SALR
HR1	RA	$P_{RA} = 0.05$	65
HR2	RA	$P_{RA} = 0.05$	65
HR3	RA	$P_{RA} = 0.05$	70
HR4	RA	$P_{RA} = 0.04$	45
HR5	RA	$P_{RA} = 0.05$	50
HR6	AD, DD	$P_{AD} = 0.06$, $P_{DD} = 0.05$	65
HR7	AD, DD	$P_{AD} = 0.055$, $P_{DD} = 0.05$	60
HR8	AD, DD	$P_{AD} = 0.05$, $P_{DD} = 0.055$	50
HR9	AD, DD	$P_{AD} = 0.04$, $P_{DD} = 0.06$	65
HR10	IMP, DD, COD	$P_{IMP} = 0.025$, $P_{DD} = 0.05$, $P_{COD} = 0.03$	55
HR11	IMP, DD, COD	$P_{IMP} = 0.025$, $P_{DD} = 0.05$, $P_{COD} = 0.03$	50
HR12	IMP, DD, COD	$P_{IMP} = 0.02$, $P_{DD} = 0.05$, $P_{COD} = 0.03$	45
HR13	IMP, DD, COD	$P_{IMP} = 0.02$, $P_{DD} = 0.03$, $P_{COD} = 0.03$	40
HR14	IMP, DD, COD	$P_{IMP} = 0.02$, $P_{DD} = 0.03$, $P_{COD} = 0.03$	40
HR15	COD	$P_{COD} = 0.02$	20
HR16	COD	$P_{COD} = 0.025$	20
HR17	COD	$P_{COD} = 0.025$	20
HR18	WTC, TST	$P_{WTC} = 0.045$, $P_{TST} = 0.04$	55
HR19	WTC, TST	$P_{WTC} = 0.04$, $P_{TST} = 0.04$	50
HR20	WTC, TST	$P_{WTC} = 0.045$, $P_{TST} = 0.035$	45
HR21	TST	$P_{TST} = 0.035$	40
HR22	TST	$P_{TST} = 0.03$	20

	TYPE	SIZE	PREA	Capable Human Resource
RA1	RA	25	No element exist	HR1, HR2, HR3, HR4, HR5
AD1	AD	25	RA1	HR6, HR7, HR8, HR9
IMP1a	IMP	10	AD1	HR10, HR11, HR12, HR13, HR14
IMP1b	IMP	15	AD1	HR10, HR11, HR12, HR13, HR14
WTC1	WTC	25	RA1	HR18, HR19, HR20
TST1	TST	25	IMP1a,IMP1b,WTC1	HR18, HR19, HR20, HR21, HR22
URA2	RA	10	No element exist	HR1, HR2, HR3, HR4, HR5
IMP2	IMP	10	URA2	HR10, HR11, HR12
TST2	TST	10	IMP2	HR18, HR19, HR20, HR21, HR22
RA3	RA	45	No element exist	HR1, HR2, HR3, HR4, HR5
AD3	AD	45	RA3	HR6, HR7, HR8, HR9
DD3a	DD	10	AD3	HR6,HR7,HR8,HR9,HR10,HR11,HR12,HR13,HR14
DD3b	DD	20	AD3	HR6,HR7,HR8,HR9,HR10,HR11,HR12,HR13,HR14
DD3c	DD	15	AD3	HR6,HR7,HR8,HR9,HR10,HR11,HR12,HR13,HR14
COD3a	COD	10	DD3a	HR10,HR11,HR12,HR13,HR14,HR15, HR16, HR17
COD3b	COD	20	DD3b	HR10,HR11,HR12,HR13,HR14,HR15, HR16, HR17
COD3c	COD	15	DD3c	HR10,HR11,HR12,HR13,HR14,HR15, HR16, HR17
WTC3	WTC	45	RA3	HR13, HR14, HR15
TST3	TST	45	COD3a, COD3b, COD3c, WTC3	HR13, HR14, HR15, HR16, HR17

The length of the capable human resource gene in the chromosome is 85 .

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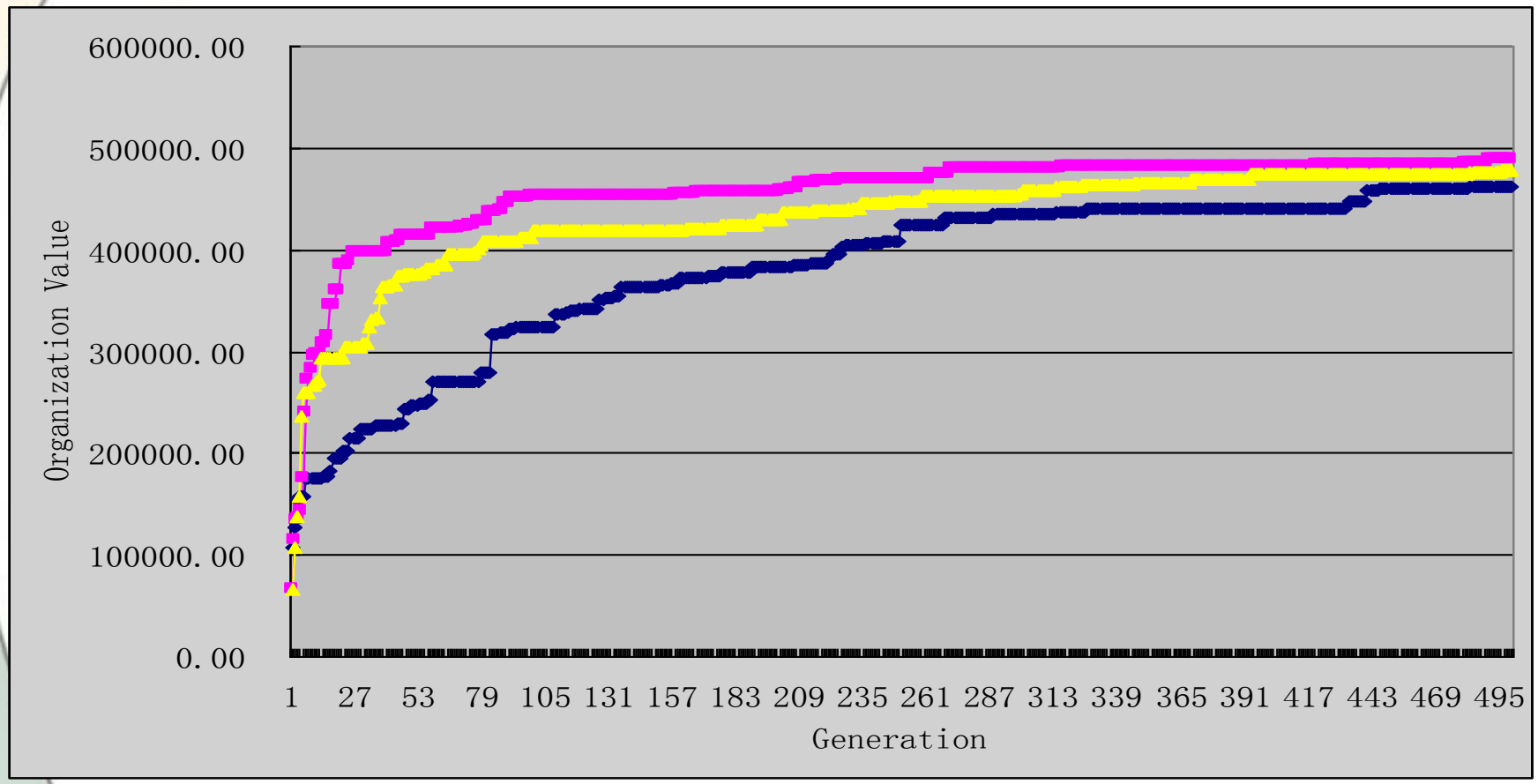
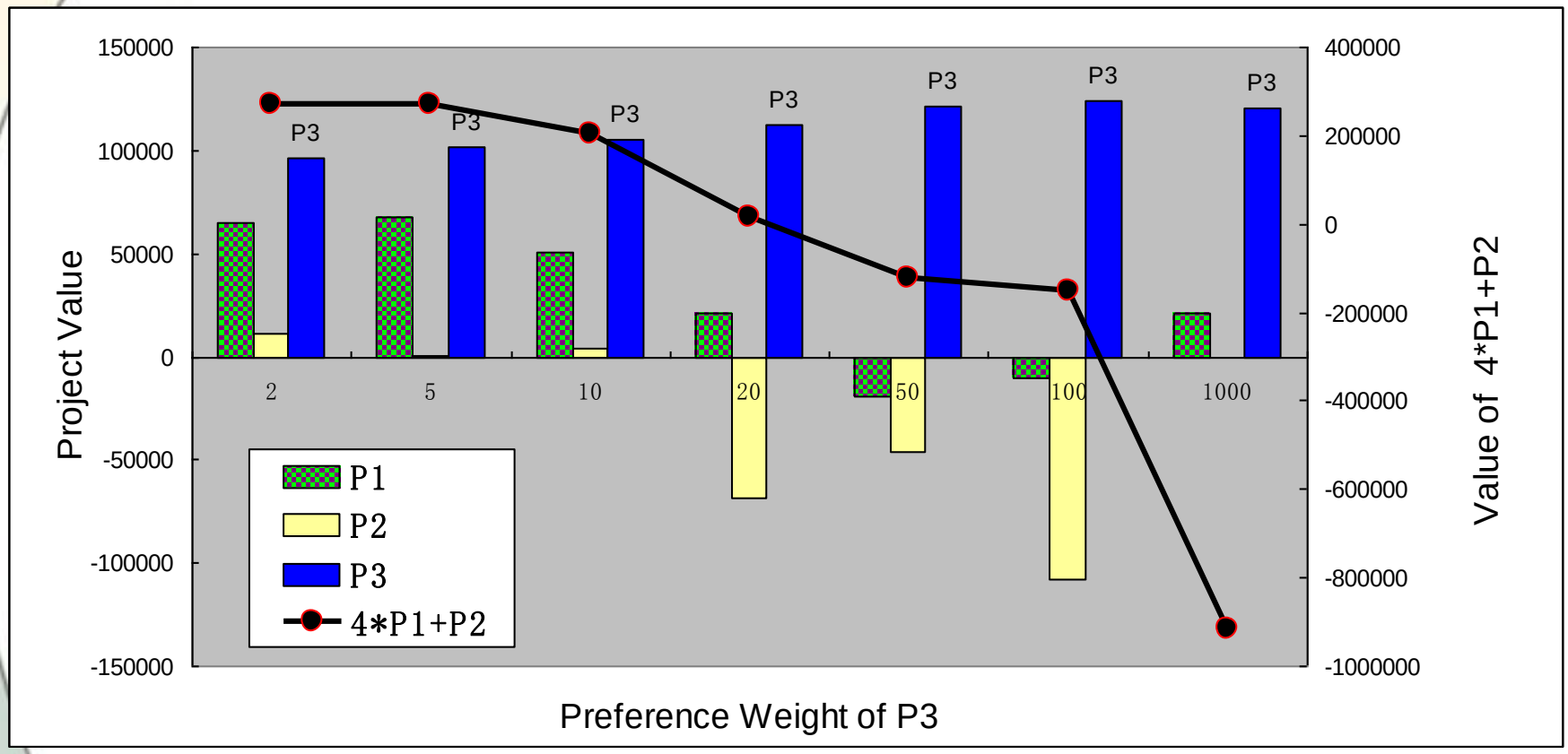
Parameters of the Genetic Algorithm

- **Population scale**: 32.
- **Priority gene size**: 3, thus the length of the chromosome is: CL = 85 + 3*19 = 142.
- **Mutation rate**: 0.01.
- **Maximum generation**: 500

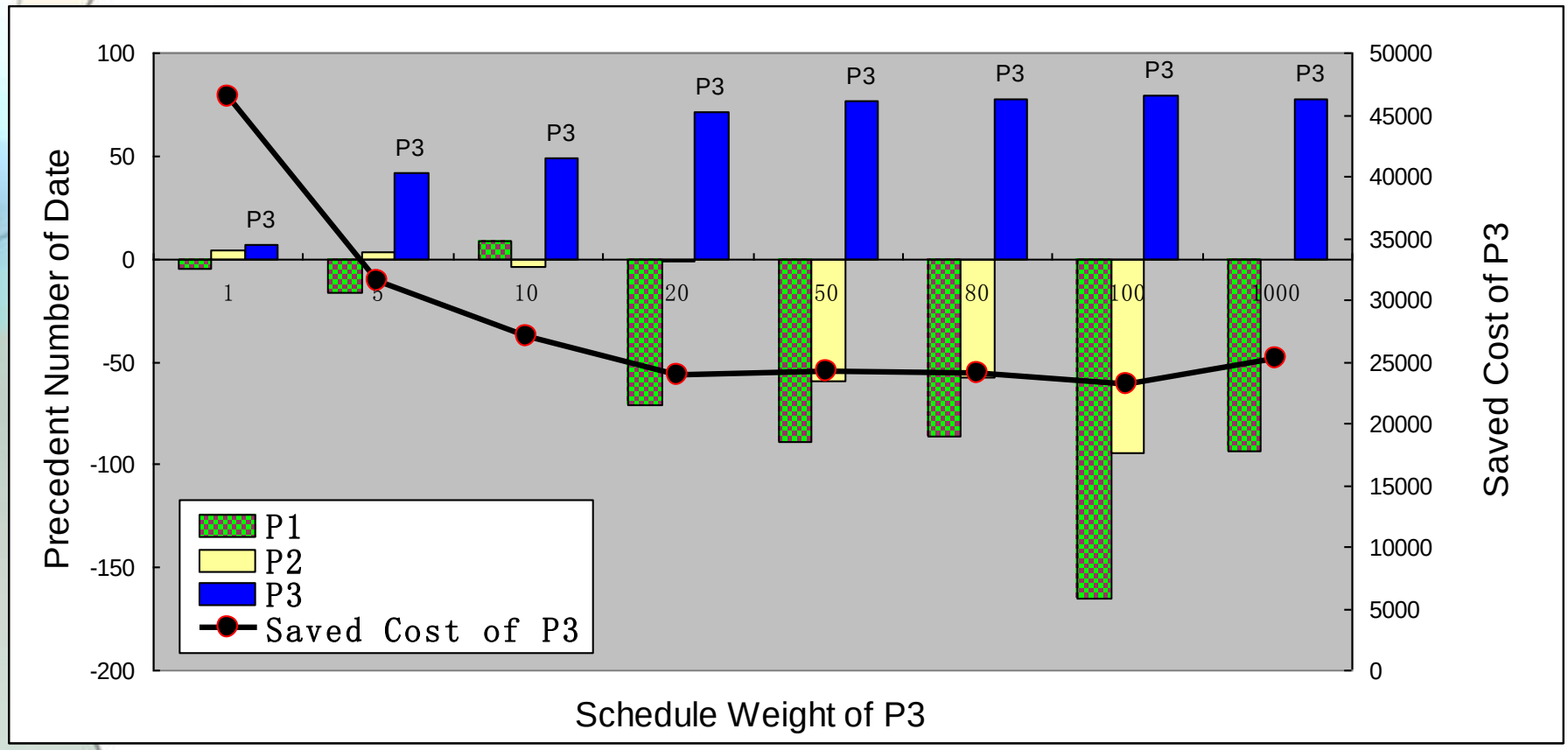
Three simulation runs of the algorithm



Project value affected by P3's PPW



Precedent number of dates according to P3's SPW



Benefit Discussions

- **A value function is defined**: it takes into account the constraints and preferences of different projects
- **The scheduling results can reflect the value objectives of the organization**: through the value function, the scheduling results will reflect the value objectives of the organization
- **Provide the decision support for project managers**: by setting different coefficients and preference weights, project managers can compare the results of the resource scheduling easily

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Conclusions

- The value function takes full consideration of the essential elements that affect the optimizing goal of scheduling such as schedule and cost.
- Based on this value function, the multi-project human resource scheduling method by using a genetic algorithm is implemented, which allows the organization to obtain a near-maximum value.
- Case study shows the method can take into account the value objectives of the organization that uses this method and effectively reflect the organization value and provide decision support for managers.

Future Work

- Learning curve of human resources
- Factors related to communication
- Overwork of human resources
- The comparison of GA with other algorithms
- Analysis and justification of GA parameters

Thank You!