Site layout of temparory construction facilities.

ACO approach

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Term presentation 2005

OUTLINE

IMPORTANCE

Find locations of temparory facilities like

- warehouses
- job offices
- workshops
- batch plants

Good layout can have an impact like

- production cost and time savings for large project.
- very large site –> large traveling distance

Objectives of Site layout.

- simplify material handling
- minimize travel time
- avoid obstructing material and equipment movements
- promote safe and efficient operations.

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Different perspectives

Tight and loose arrangement of facilities

- space between facilites in loose
- loose spacing suitable to construction

Static vs. dynamic layout

- time dependent arrangement of facilites.

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Perspectives contd..

Layout improvement vs. layout construction algorithm

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- interchange predetermined layout to get better layout
- in latter start from scratch

Site shape

- rectangualar most common
- unequal area
- facility as group of unit area

Perspectives contd..

Layout improvement vs. layout construction algorithm

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Perspectives contd..

Parameters used to find objective function

- consruction cost
- frequency of trips
- flow volume of different resources
- desirability of adjacency
- interaction cost

Optimization vs. heuristic approach

- heuristic rules , experience and simplified approaches
- mathematical optimization difficult for limited no. of facilities

Perspectives contd..

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Optimization vs. heuristic approach

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Recent trend

Use of following solution techniques.

- Non-traditional techniques
- Artificial intelligence
- Genetic Algorithms
- Artificial neural networks
- Simulated annealing
- in this work Ant colony optimization

Site Layout with annealed neural network by Yeh 1995.

Important Features

- Formulation as combinatorial optimization problem
- Predetermined set of facilites on predetermined set of sites.
- Rectangular shape sites.
- Static layout
- Solution using hybrid of Artificial neural networks & Simulated annealing
- Cost is interaction between adjacent facilites.

Formulation as combinatorial optimization problem.

Decision Variables

- $\mathfrak{L} = \{\mathfrak{l}_1, \mathfrak{l}_2, \ldots, \mathfrak{l}_i, \mathfrak{l}_{n_f}\}$
- $\mathfrak{l}_i$ is the location of i th facility
- and n_f is the number of facilies i.e dimension of decision vector $\mathfrak{L}$.
- Variable bounds : $1 \leq \mathfrak{l}_i \leq n_s$
- n_s is the number of available sites.

Formulation as combinatorial optimization problem.

Objective function

- $\mathfrak{F}(\mathfrak{L}) = \sum_x \sum_i \delta_{xi}(c)_{xi} + \sum_x \sum_y \sum_i \sum_j \delta_{xi}\delta_{yj}A_{xy}D_{ij}$
- where

$$\text{if } \mathfrak{l}_i = x \quad \text{then } \delta_{xi} = 1$$
$$\text{if } \mathfrak{l}_i \neq x \quad \text{then } \delta_{xi} = 0$$

and

$$A_{xy} = 1 \quad \text{if site } x \text{ adjacent to site } y$$
$$A_{xy} = 0 \quad \text{otherwise}$$
$$D_{xy} = \text{ distance between site } x \text{site } y$$

Formulation as combinatorial optimization problem.

Equality Constraints

- One facility should be allocated to onl one site. $\sum_x \delta_{xi} = 1$
- One site can accomodate only one facility. $\sum_i \delta_{xi} = 1$

Site level facilities layout with genetic algorithms Li and Love 1998.

Important Features

- Rectangular shape sites.
- Size of sites is unequal.
- Static layout
- Solution using genetic algorithms
- Cost is product distance between site and frequency of trips

Formulation .

Decision Variables

Same as Yeh 1995

Types of site considered

$\mathcal{S}_l$ is set of smaller site locations

$\mathcal{S}_l \subset \{1, 2, \ldots, n_s\}$

$0 < \text{kardinality}(\mathcal{S}_l) < n_s$

which cant accomodate facilites in set $\mathcal{F}_v$

$\mathcal{F}_v \subset \{1, 2, \ldots, n_f\}$

$0 < \text{kardinality}(\mathcal{F}_v) < n_f$

Li and Love's Formulation .

Objective function

- $\mathfrak{F}(\mathfrak{L}) = \sum_x \sum_y \sum_i \sum_j \delta_{xi}\delta_{yj} d_{xy} f_{ij}$
- where

$$\begin{aligned} &\text{if} \quad \mathfrak{l}_i = x \quad \text{then} \quad \delta_{xi} = 1 \\ &\text{if} \quad \mathfrak{l}_i \neq x \quad \text{then} \quad \delta_{xi} = 0 \end{aligned}$$

and

$$\begin{aligned} f_{ij} &= \text{frequency of trips between facility } i \text{facility } j \\ d_{xy} &= \text{distance between site } x \text{site } y \end{aligned}$$

Li and Love's Formulation .

Equality Constraints

Same as Yeh 1995

Additional Constraints due to big facility and small sites.

if $x = \mathfrak{l}_i$
then $x \notin \mathcal{S}_l$ or $i \notin \mathcal{F}_v$

Precast site layout with genetic algorithms Cheung et al 2002

Important Features

- Special considerations for precast construction
- Different types of resource flows
- Formulation similar to used by Li and Love 1998

Cheung et al's Formulation .

- decision variables.
- Constraints .
- Objective Function .

as Li and Love .

Different definition of flow between two facilites.

$f_i j = \sum_{m=1}^{n_r} cost_m F_{mij}$ where
F_{mij} is volume of flow of resource m between facility i and j.
$cost_m$ is unit cost of flow of resource m.

CHEUNG ET AL'S FORMULATION .

- decision variables.
- Constraints .
- Objective Function .

as Li and Love .

DIFFERENT DEFINITION OF FLOW BETWEEN TWO FACILITES.

$f_i j = \sum_{m=1}^{n_r} cost_m F_{mij}$ where
F_{mij} is volume of flow of resource m between facility i and j.
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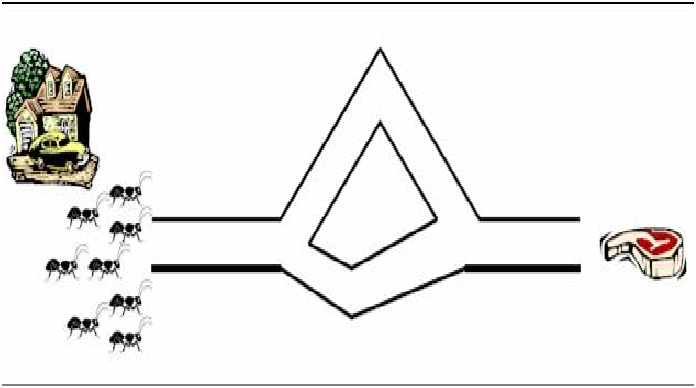
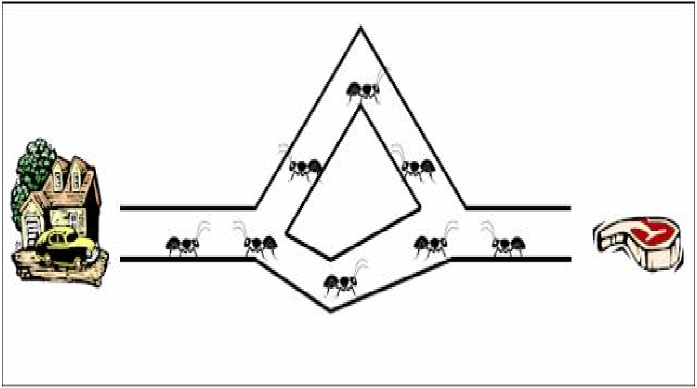
Real ants behaviour.



EMERGING REAL ANTS BEHAVIOUR.



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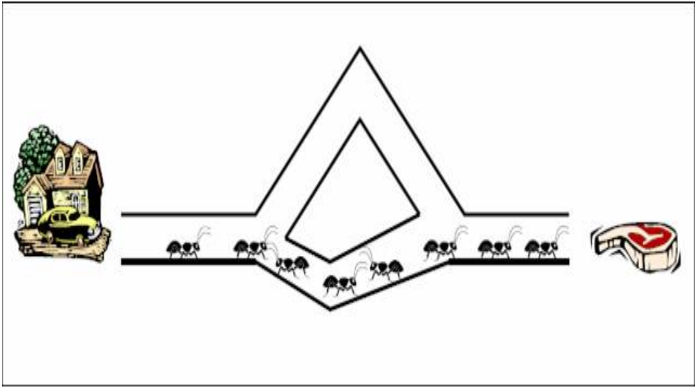


Formulation for Ant Colony optimization application

Definition

A model $P = (S, \Omega, f)$ of a site layout problem consists of:

- *a **search (or solution) space** $\mathcal{S}$ and a set Ω **constraints** among the variables;*
- *an **objective function** $f : \mathcal{S} \rightarrow \mathcal{R}^{+}$ to be minimized.*

*The search space $\mathcal{S}$: Given n_f **discrete variables** $\mathfrak{l}_i$ with domains $D_i = 1, \cdots, n_s, i = 1, \cdots, n_f$. A variable instantiation, that is, the assignment of a value i to a variable $\mathfrak{l}_i$, is denoted by $\mathfrak{l}_i = i$.*

Formulation for Ant Colony optimization application

- A feasible solution $s \in \mathcal{S}$ is a complete assignment (i.e., an assignment in which each decision variable has a domain value assigned) that satis.es the constraints.
- A feasible solution $s^* \in \mathcal{S}$ is called a **globally optimal solution**, if $f(s^*) \leq f(s) \ \forall s \in \mathcal{S}$
- The set of globally optimal solutions is denoted by $\mathcal{S}^* \subseteq \mathcal{S}$
- To solve a site layout problem one has to find a solution $s \in \mathcal{S}^*$

Terminology

- combination of a decision variable $\mathcal{X}_i$ and one of its domain values v_i^j a *solution component* denoted by $\mathbf{c}_i^j$.
- trail parameter $\mathcal{T}_i^j$ for every solution component $\mathbf{c}_i^j$.
- The value of a *pheromone* trail parameter $\mathcal{T}_i^j$ called pheromone value – is denoted by τ_i^j .
- The set of all pheromone trail parameters is denoted by $\mathcal{T}$.
- of all solution components$\mathfrak{C}$

- A solution construction starts with an empty partial solution $\mathfrak{s}_p = \langle\rangle$.
- at each construction step the current partial solution $\mathfrak{s}_p$. is extended by adding a feasible solution component from the set $\mathfrak{N}(s_p)$
- Definition: $\mathfrak{N}(s_p) = \mathfrak{C} \backslash \{ \, c_m^n \mid m \leq \psi, \; \mathfrak{l}_m = n \}$
- This can be regarded as a walk (or a path) on the so-called construction graph $\mathcal{G}_C = (\mathfrak{C}, \mathfrak{L})$,
- vertices are the solution components $\mathfrak{C}$
- and the set $\mathfrak{L}$ are the connections.
- The allowed walks on $\mathcal{G}_C$ defined by the set $\mathfrak{N}(s_p)$ with respect to a partial solution $\mathfrak{s}_p$.

- We denote the set of all solution that may be constructed in this way by $\mathfrak{S}$.
- The choice of a solution component from $\mathfrak{N}(s_p)$ is done probabilistically
- the probabilities for choosing the next solution component are defined as follows:

$$p(\mathfrak{c}_i^j|\mathfrak{s}_p) = \frac{{\tau_i^j}^\alpha}{\sum_{\mathfrak{c}_k^l \in \mathfrak{N}(s_p)} {\tau_i^l}^\alpha} \ , \quad \forall \mathfrak{c}_k^l \in \mathfrak{N}(s_p) \ , \qquad (1)$$

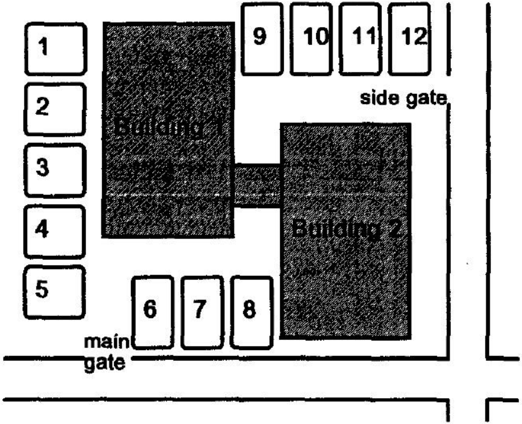
- α is a parameter .

- Most ACO algorithms use the following pheromone value update rule:

$$\tau_i^j \leftarrow (1-\rho)\tau_i^j + \rho \sum_{\{\mathfrak{s}\in\mathfrak{S}_{upd} \mid c_i^j\in\mathfrak{s}\}} F(\mathfrak{s}), \qquad (2)$$

- for $i = 1, \cdots, n$, and $j \in \{1, \cdots, |\mathcal{D}_i|\}$.
- $\rho \in (0,1]$ is a parameter called evaporation rate.
- $F : \mathfrak{S} \mapsto R^+$ is a function such that
- $f(\mathfrak{s}) < f(\mathfrak{s}\prime) \Rightarrow F(\mathfrak{s}) \geq F(\mathfrak{s}\prime), \;\; \forall \mathfrak{s} \neq \mathfrak{s}\prime \; \in \mathfrak{S}.$
- Instantiations of this update rule are obtained by different specifications of $\mathfrak{S}_{upd} \subseteq \mathfrak{S}_{iter} \bigcup \{\mathfrak{s}_{bs}\}$

Example from Yeh 1995 .



Example from Yeh 1995 .

- data for adjacency and interaction cost assumed
- implemented in C programming language.
- Optimum value found is 90.0
- Yeh obtained a value of 93.0

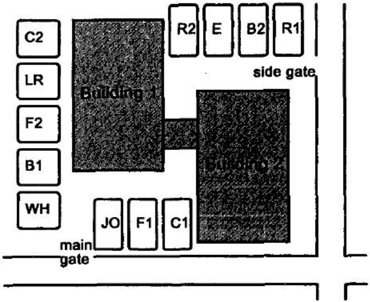
ACO PROCEDURE

Algorithm: ACO procedure

```
InitializePheromoneValues(T) ;
while Termination criteria not true do
    for each ant k do
        s ← ConstructSolution(T) ;
    end
    ApplyPheromoneUpdate(T, S_iter, s_bs) ;
end
Output: The best– so– far solution s_bs
```

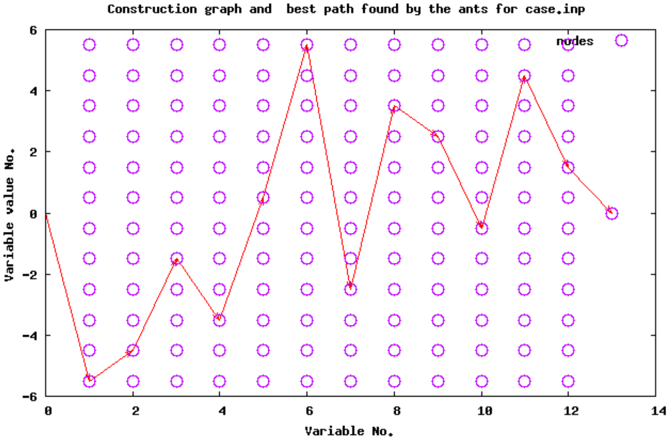
InitializePheromoneValues($\mathcal{T}$) ;
while *Termination criteria not true* **do**
  for *each ant k* **do**
    $\mathfrak{s} \leftarrow$ ConstructSolution($\mathcal{T}$) ;
  end
  ApplyPheromoneUpdate($\mathcal{T}, \mathfrak{S}_{iter}, \mathfrak{s}_{bs}$) ;
end
Output: The best– so– far solution $\mathfrak{s}_{bs}$

OPTIMUM LAYOUT .



R1= rein. steel shop No.1.
R2= rein. steel shop No.2.
C1= carpentry shop No.1.
C2= carpentry shop No.2.
F1= falsework shop No.1.
F2= falsework shop No.2.
B1= concrete batch plant No.1.
B2= concrete batch plant No.2.
JO= job office.
LR= labour residence.
E = electricity equipment and water supply shop.
WH= warehouse.

SOLUTION CONSRUCTION GRAPH USED BY ANTS.



SUMMARY

- Site layout problem was formulated as combinatorial optimization problem
- Solution construction mechanism for use with ACO was defined.
- Formulation gives only feasible solutions which is not so with Yeh 1995.