DISMA Dipartimento di Scienze Matematiche G. L. Lagrange

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Blood Platelet Inventory Management
Business Analytics

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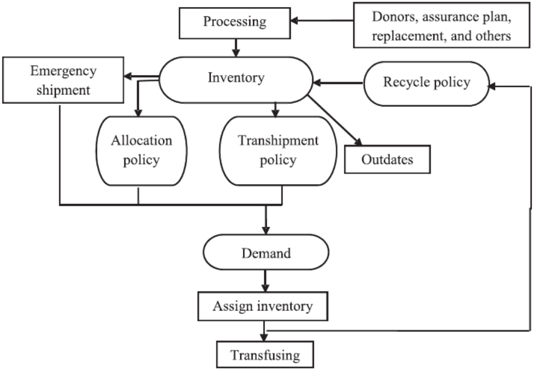
Outline

Narrative

The next slides introduce the blood platelet bank problem with the **approximate dynamic programming (ADP)** approach.
In particular the problem regards the management of a bank blood inventory.



Single-period model

Network's composition:

- 162 (27 $\times$ 6) supply nodes
- 8 demand nodes
- 48 inventory nodes

Process:

- **Start**: addition of the newly arrived platelets and the removal of outdated units (more than six-days old), followed by serving the incoming demand
- **End**: at the end of day t, all inventory is updated with the actual donation (supply) and demand.

Indices

- i: Blood platelet types removed from the inventory to serve demand, where $i = 1, 2, ..., 8$ for AB+, AB-, A+, A-, B+, B-, O+, O-, respectively.
- j: Blood platelet age, $j = 1, 2, ..., 6$, where 1 indicates new blood platelets and more than 6 means the blood platelet can no longer be used.
- k: Requested blood platelet types that are served by blood platelet types in the inventory, where $k = 1, 2, ..., 8$, for $1 = AB+, 2 = AB-, 3 = A+, 4 = A-, 5 = B+, 6 = B-, 7 = O+, 8 = O-$.
- n: Replications per year, where $n = 1, 2, ..., 200$.
- t: Given day in a year; the process runs daily for a year, where $t = 1, 2, ..., 365$.

Parameters

- N_i: Maximum Inventory capacity for blood type i.

Variables

- y_{kt}: Total actual demand for blood type k on a given day t, i.e., $y_t = \sum_k y_{kt}$, and $\hat{y}_t$ is the expected demand.
- x_{ijt}: Number of units of blood platelets of type i and age j removed from inventory to satisfy demand y_{kt} during day t, and $x_t = \sum_i \sum_j x_{ijt}$.
- x_{ts}: Total same blood platelet type i obtained from the inventory during day t to satisfy same demand y_{it}; x_{td} is the total units used to satisfy demand y_{it} with different than blood type i and not $O-$, and x_{tO-} is the total units of blood type $O-$ used to satisfy demand y_{it}, where $i \neq O-$.
- u_t: The total unsatisfied demand at the end of day t.
- z_{ijt}: Actual unused blood platelet inventory of type i and age j at the end of day t.

- I_{ijt}: Available inventory at the beginning of day t; I_t^1 is the total beginning inventory for day $t = 1$, I_t^n is the total inventory on day t at replication n, where $I_t = \sum_i \sum_j I_{ijt}$
- I_t^{χ}: Daily inventory after updating it with the actual demand at the conclusion of day t and donation during time t.
- Q_t: Up-to-order quantity at the beginning of day t calculated using news-vendor type model.
- p_{it}: Actual donation of type i with age $j = 1$ received at the beginning of day t; $\hat{p}_{it}$ is the estimated ordered quantity.
- D_{it}: Blood platelets of type i with age $j > 6$ removed from inventory at the beginning of day t. They are considered outdated units.
- e_t: Exogenous information that becomes available at the end of day t, where $e_t = (\hat{y}_t, \hat{p}_{it})$ or the expected demand and donation at the beginning of time t, and y_t, p_{it} are the actual demand and donation received during time t.

Constraints

$$p_{i,t+1} = min((Q_{it} - \sum_i z_{i6t}), y_{it-1}), \qquad \forall i \tag{1}$$

$$I_t = \sum_i \sum_j z_{i,j,t-1} + p_{it} \tag{2}$$

$$D_{it} = z_{i6(t-1)} \qquad \forall i \tag{3}$$

$$\sum_i y_{it} = y_t \tag{4}$$

$$u_t = y_t - \sum_i \sum_j x_{ijt} \qquad \forall k \tag{5}$$

$$x_{ts} = \sum_k y_{kt} - \sum_i \sum_j x_{ijt} - u_t \qquad i = k \tag{6}$$

$$x_{td} = \sum_k y_{kt} - \sum_i \sum_j x_{ijt} - u_t \qquad i \neq k \tag{7}$$

$$x_{tO-} = \sum_k y_{kt} - \sum_i \sum_j x_{ijt} - u_t \qquad i \neq 8, i = k \tag{8}$$

$$\sum_i \sum_j x_{ijt} = x_{ts} + x_{td} + x_{tO-} \tag{9}$$

$$\sum_i \sum_j x_{ijt} \leq y_{kt} \tag{10}$$

$$\sum_j z_{ijt} \leq N_{it} \qquad \forall i \tag{11}$$

$$x_{ijt} \geq 0, z_{ijt} \geq 0, u_t \geq 0, D_{it} \geq 0 \tag{12}$$

Objective function: $C_t(I_t) = C_s x_{ts} + C_d x_{td} + C_{o-} x_{to-} - C_u u_t - C_g \sum_i D_{it}$
$- C_h \sum_i \sum_j z_{ijt} - 0.5 \sum_j (j \sum_i x_{ijt})$

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Two strategies for designing policies

Policy search

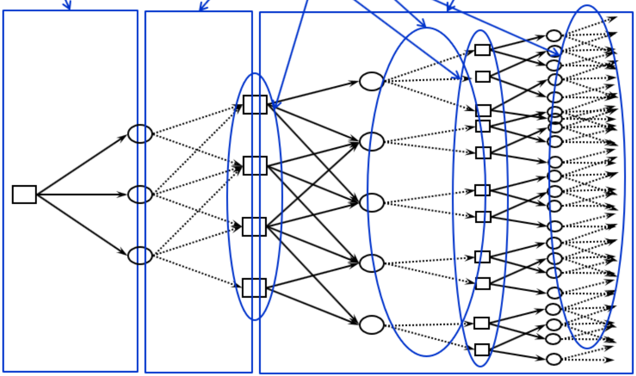
$$\max_{\pi=(f\in F,\theta^f\in\Theta^f)} E\left\{\sum_{t=0}^{T} C\left(S_t, X_t^{\pi}(S_t \mid \theta)\right) \mid S_0\right\}$$

Lookahead approximations

$$X_t^*(S_t) = \arg\max_{x_t}\left(C(S_t,x_t) + \mathrm{E}\left\{\max_{\pi\in\Pi}\left\{\mathrm{E}\sum_{t'=t+1}^{T} C(S_{t'}, X_{t'}^{\pi}(S_{t'})) \mid S_{t+1}\right\} \mid S_t, x_t\right\}\right)$$

Approximate DP

$$X_t^*(S_t) = \arg\max_{x_t} \left(C(S_t, x_t) + \mathrm{E}\left\{ \max_{\pi \in \Pi} \mathrm{E}\left\{ \sum_{t'=t+1}^{T} C(S_{t'}, X_{t'}^{\pi}(S_{t'})) \mid S_{t+1} \right\} \mid S_t, x_t \right\} \right)$$



Approximate DP

An optimal policy (based on looking ahead):

$$X_t^*(S_t) = \arg\max_{x_t} \left(C(S_t, x_t) + \mathrm{E}\left\{ \max_{\pi \in \Pi} \left\{ \mathrm{E} \sum_{t'=t+1}^{T} C(S_{t'}, X_{t'}^{\pi}(S_{t'})) \mid S_{t+1} \right\} \mid S_t, x_t \right\} \right)$$

We can approximate the lookahead model using:

$$X_t^*(S_t) = \arg\max_{x_t} \left(C(S_t, x_t) + \mathrm{E}\left\{ V_{t+1}(S_{t+1}) \mid S_t, x_t \right\} \right)$$

$$X_t^{VFA}(S_t) = \arg\max_{x_t} \left(C(S_t, x_t) + \mathrm{E}\left\{ \overline{V}_{t+1}(S_{t+1}) \mid S_t, x_t \right\} \right)$$

$$= \arg\max_{x_t} \left(C(S_t, x_t) + \overline{V}_t^x(S_t^x) \right)$$

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We can then approximate the V.F. using:

$$\bar{V}_t(I_t^x) = \sum_{b \in B} \bar{V}_{tb}(I_{tb}^x)$$

$$\frac{\partial \bar{V}_t(I_t)}{\partial I_{t-1}} = v_t^n$$

$$\bar{V}_t^{n-1}(I_t) = \sum v_t^n x_{ijt}$$

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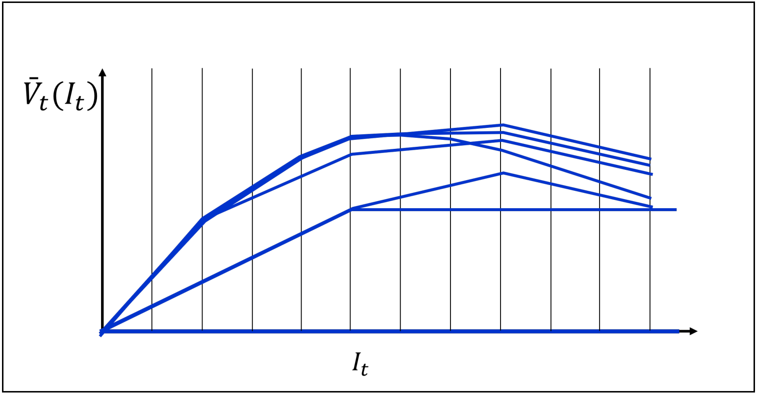
- Derivatives are used to estimate a piece-wise linear approximation



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Results and discussion

To run the algorithm three different supply policies were used. FIFO, LIFO and Circular. Additionally each of the policies is compared with a myopic policy. The results are shown here:

Comparison of the three policies.

Policy	Outdated	Shortage	Total inv.	Reward	Myopic outdated	Myopic shortage	Myopic reward	Myopic total inv.
FIFO	4.6	3.9	38	17.0	9.6	6.4	46	2.1
Circular	5.0	4.8	45	13.5	9.5	5.5	53	2.2
LIFO	5.8	7.3	62	10.5	9.8	8.1	69	2.0

Below, some plot describing outdates and shortage percentage in different situations.

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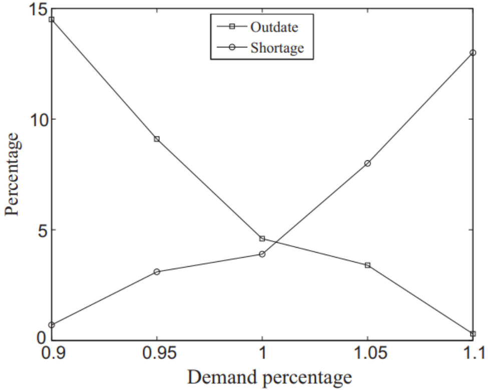

Figure: FIFO demand variation

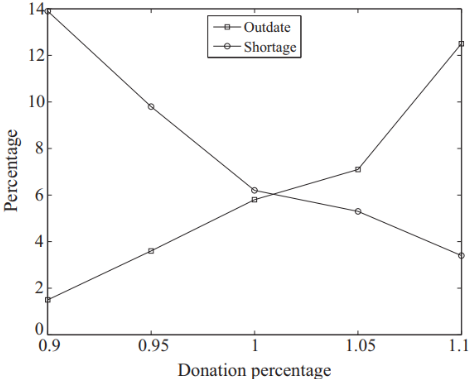

Figure: LIFO donation variation

Conclusion

In conclusion, considering the outdates and shortage percentage we can affirm that FIFO policy is actually the best policy to use.

Thank you for the attention

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