Integration of Nonlinear CDU Models in Refinery Planning Optimization

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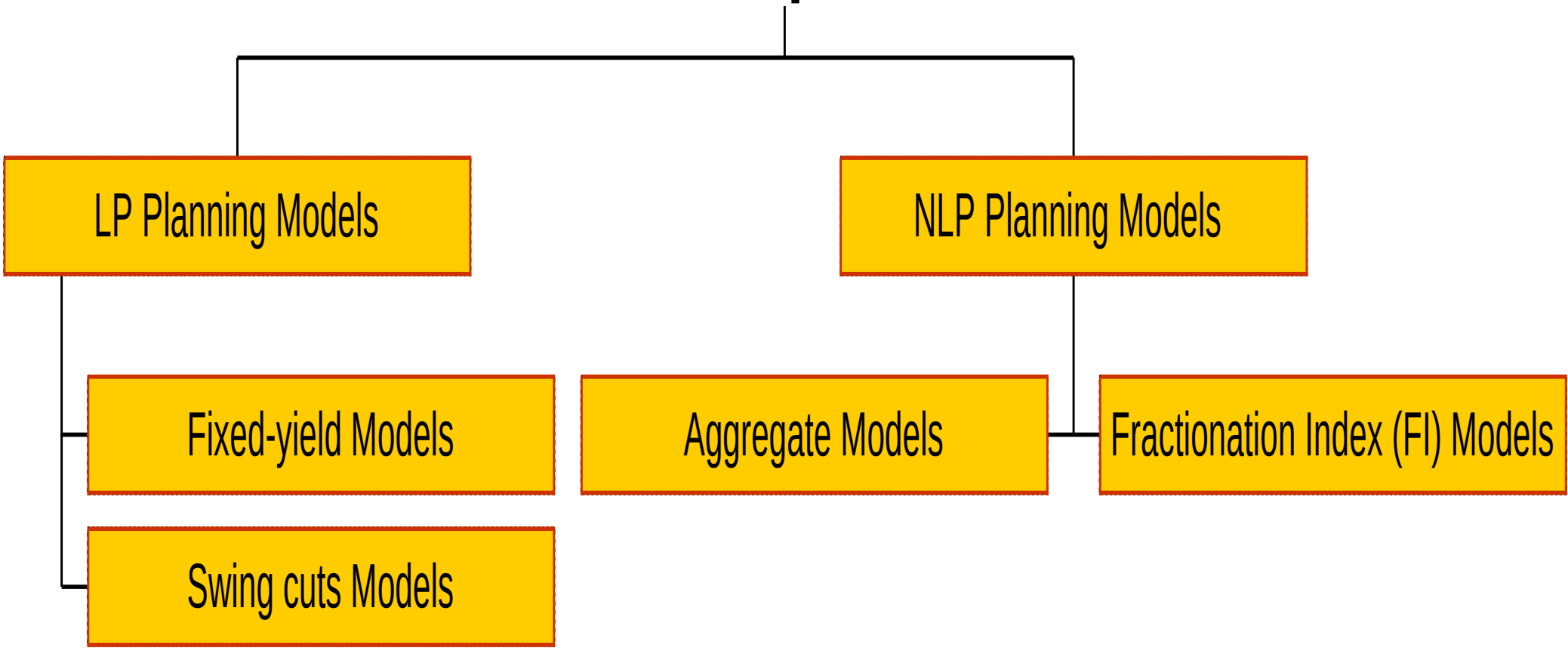
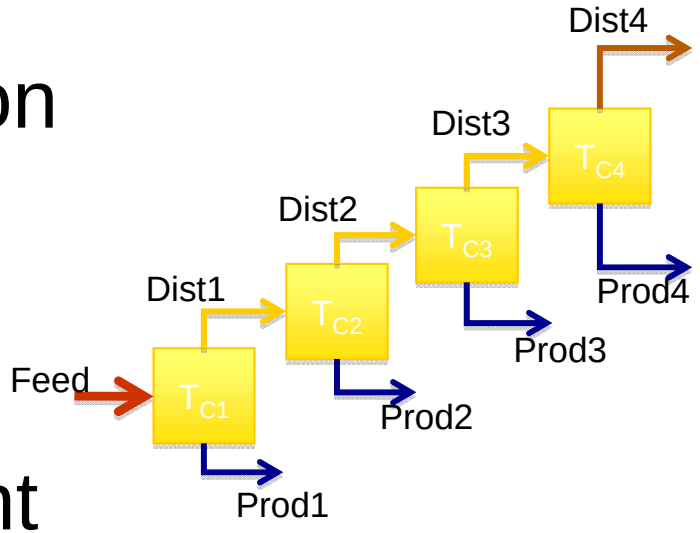
Refinery Planning Model Development



FI Model - Intro

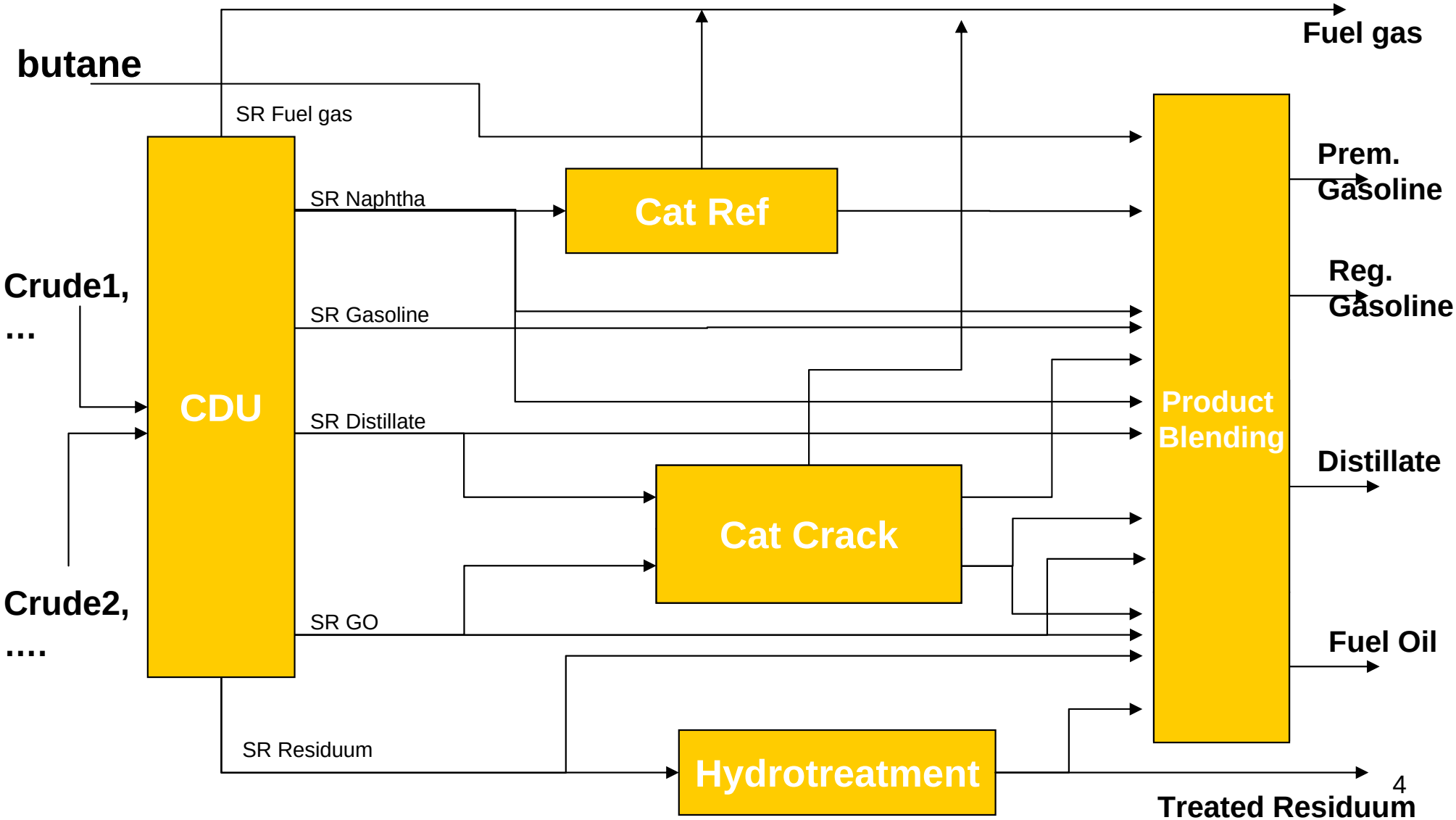
- CDU is a series of fractionation units
  - Cut point temperature is the separation temperature



- FI Model is crude independent
  - FI values are characteristic of the column
- Avoids more complex, nonlinear modeling equations
- Generates cut point temperature settings for the CDU

Planning Model Example

Typical Refinery Configuration *(Adapted from Aronofsky, 1978)*



Planning Model Example

- Information Given
  - Refinery configuration: Process units
  - Cases: Processing 2,3 & 4 crude oils
- Objective
  - Select crude oils and quantities to process
    - Maximize profit
    - single period time horizon
- Economics
  - FI calculates the maximum profit scenario

Crude1	Louisiana	Sweet	Lightest
Crude2	Texas	Sweet	
Crude3	Louisiana	Sour	
Crude4	Texas	Sour	Heaviest

Model	2 Crude Oils Case	3 Crude Oils Case	4 Crude Oils Case
FI	245	249	247
LP-SC	195	195	191
LP-FY	51	62	59

Multi-period Refinery Planning

- Extending the single period model to multi-period horizon
  - Each period is 1 week, with potential production time for each crude and change-overs
  - Product demands are specified at the end of each period
  - Change-over times and costs are sequence-dependent
  - Only product storage is considered
- Objective
  - Specify crude oil processing rate, time and sequence that maximize profit

Multi-period Refinery Planning Model

- Assignment

$$\theta_{cr,t} \leq H_t * YP_{cr,t}$$
$$F_{cr,t} * \theta_{cr,t} \leq CrAvail_{cr,t}$$
$$Inv_{p,t} = Invi_{p,t} + \sum_{p} rP_{p,cr,t} * \theta_{cr,t}$$
$$S_{p,t} \geq D_{p,t}$$

- Sequence

$$YP_{cr,t} = \sum_{cr} ZP_{cr,ccr,t} \qquad YP_{ccr,t} = \sum_{ccr} ZP_{cr,ccr,t}$$
$$YP_{cr,t} \geq ZP_{cr,cr,t} \qquad YP_{ccr,t} + ZP_{cr,cr,t} \leq 1$$
$$ZP_{cr,cr,t} \geq YP_{cr,t} - \sum_{ccr \neq cr} YP_{ccr,t}$$
$$\sum_{cr}\sum_{ccr} ZZP_{cr,ccr,t} = 1 \qquad ZZP_{cr,ccr,t} \leq ZP_{cr,ccr,t}$$

- Transition time & time balance

$$TTrans_t = \sum_{cr}\sum_{ccr} \tau_{cr,ccr} * ZP_{cr,ccr,t} - \sum_{cr}\sum_{ccr} \tau_{cr,ccr} * ZZP_{cr,ccr,t}$$
$$\sum_{cr} \theta_{cr,t} + TTrans_t + [\sum_{cr}\sum_{ccr} tau_{cr,ccr} * ZZZ_{cr,ccr,t}] = H_t$$

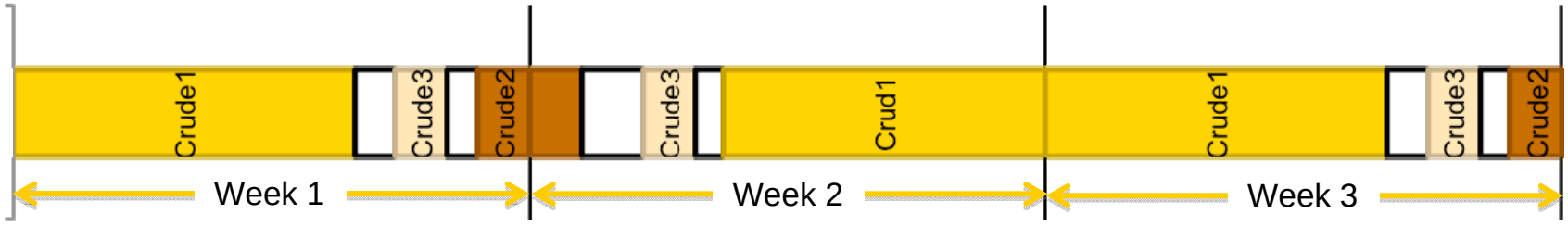
- Objective function

$$Profit = \sum_{t}\sum_{p} CP_{p,t} * S_{p,t} - \sum_{t}\sum_{cr} CF_{cr,t} * F_{cr,t} * \theta_{cr,t} -$$
$$\sum_{t}\sum_{cr} OpCost_{cr,t} * \theta_{cr,t} - \sum_{t}\sum_{p} Cinv_{p,t} * Inv_{p,t} -$$
$$\sum_{t}\sum_{cr} CTrans * TTrans_t$$

Multi-period Refinery Planning Model Example

- Extending the single-period model
  - 3 time periods
  - 3 crude oil feeds
  - Solver: DICOPT
    - Equations: 5536
    - Variables: 5653
      - Nonlinear: 1746
      - Binary: 126
    - Solution time: 49 sec

Profit	**2944**
Sales	16541
Crude oil cost	11592
Feedstock cost	50
Operating cost	571
Inventory cost	1015
Transition cost	370



Conclusion

- Proposed FI model
  - Crude independent
  - Calculates cut point temperature settings
- Multi-period Extension
  - Traveling salesman problem
    - Sequence dependent change-overs
  - Solution includes crude processing times and sequence
  - More example runs
    - More crude oils and time periods
    - Improving robustness

Thank You