ATTEND
Analytical Tools for Evaluating Negotiation Difficulty

Alejandro Bugacov    Murilo Coutinho
Peter Will            Robert Neches
USC Information Sciences Institute
May, 2000
Key Ideas: Difficulty Warnings that Allow Negotiation Systems to Adapt

- **Partition task space** into
  - Those that truly require negotiation
  - Those that can be solved analytically

- **Identify groups** with different level of difficulty

- **Negotiation difficulty warnings** based on problem complexity

- **Techniques made available** to any negotiation system via a general API
Impact on Negotiations:
Adapt to Time & Quality

• Systems lack analytical methods to estimate negotiation difficulty and adapt their behavior accordingly:
  • Can negotiations find any solution in the time available? → Convergence
  • Can negotiations find solutions with the desired quality and time constraints? → Closure
  • Can external changes destabilize the system? → Stability
Relation of Techniques Under Consideration to Technical Goals

- Identify tasks that truly require negotiations
- Form groups with different difficulty level
- Generate difficulty warnings by group

API

Graph Coloring  Phase Transition  Graph Partitioning
Graph Coloring  Graph Partitioning

USC ISI - ATTEND
Resolving Resource Conflicts: Graph-coloring

- Treat as a system of interacting magnets
- Associate colors with vector orientations

Solve → Minimize the Energy of the System

\[ E = \frac{1}{2} \sum_{ij} w_{ij} \vec{S}_i \cdot \vec{S}_j \]
Statistical Mechanics Approach: Color-flipping Mechanism

\[ E = \frac{1}{2} \sum_{ij} w_{ij} \cdot \vec{S}_i \cdot \vec{S}_j \]

Track the energy relaxation with the number of color flips during minimization using a Metropolis-type algorithm.

Fast relaxing nodes \( \rightarrow \) Low difficulty

Slow relaxing \( \rightarrow \) High difficulty

USC ISI - ATTEND
Algebraic Approach:
Linear, Quadratic and Integer Programming

\[ E = \frac{1}{2} \sum_{ij} w_{ij} \vec{S}_i \cdot \vec{S}_j \quad \iff \quad E = \frac{1}{2} \left[ s^T \cdot A \cdot s - N \right] \]

- Minimization of \( E \) with binary constraints
- Conjugate gradient algorithm \( \rightarrow A \cdot s = b \)
  - Iteratively improve solutions
  - Linear scaling with number of nodes

\[ s^T = [1 \ 0 \ 0 \ 0 \ 0 \ 1 \ \ldots \ \ldots \ \ldots \ 0 \ 1 \ 0] \]

\[ A= \]

Connectivity Matrix

State Vector

USC ISI - ATTEND
Phase-Transitions: Problem Difficulty Characterization

- Use transition curves and local value of the order parameter to:
  - Identify groups with different difficulty level
  - Generate difficulty warnings by groups

\[ K_i = \text{number of available colors per node} \]
Graph Partitioning Techniques: Clique Separation

Set of Tasks with high negotiation difficulty

Task space subdivided into regions of decreasing negotiation difficulty

Identify clique that separates task into two regions

Continue until no more clique separators are found
Graph Partitioning Techniques:
Minimum Edge Cutting

Set of Tasks with high negotiation difficulty

Dissect the graph into two groups using a minimum edge cutting line

Continue until negotiation difficulty in each subgroup decreases to an acceptable low level

Task space subdivided into regions of decreasing negotiation difficulty

USC ISI - ATTEND
Current Status: Activities in Progress

Performing a trade-off analysis between alternative graph partition and coloring techniques.

Developing detailed integration plan:
- CAMERA and its current application
- Possible other ANT's efforts

Refining incremental implementation plan.
Progress Evaluation: Increasing Predictive Power, Provided More Quickly

- Evaluate problems collected from CAMERA and show that they can be characterized within our formalism
- Test ATTEND using advance difficulty warnings to let application dynamically adjust its negotiation strategy
- API specifications and implementation
- Measure correlation between difficulty predictions and empirical system data
- Develop and Implement difficulty warnings and cluster identification techniques
- GFY 2001
- GFY 2002
- GFY 2003
Summary:
ATTEND Will Deliver …

Set of techniques to provide negotiation difficulty warnings that will enable systems to rapidly adapt to time & quality constraints

API to make the techniques available to people who want to use them

Demonstration of the effectiveness of the techniques through a tie to CAMERA