National Matching Services Inc.

Issues in Real-World Matching Market Design

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National Matching Services Inc.

- Dedicated to development and operation of Matching Programs in a variety of major professions
- Services: turnkey administration, software, consulting
- Established in 1985, but experience with matching pre-dates NMS

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Topics To Be Covered

- A Matching Program
- Selling the concept
- Defining the rules
- Program administration
- Matching algorithm
- Complex requirements
- Legal Issues

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A Matching Program

- Two-sided matching of applicants to positions
  - Each side of the market has preferences for the other side of the market
  - A participant needs to both choose and be chosen
- Each participant submits an ordered list of preferences (1st choice, 2nd choice, etc.)
- Applicants allocated to positions using a centralized matching mechanism based on the stated preferences

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Examples of Current NMS Matches

- **Dental** residencies
- **Psychology** pre-doctoral internships and some post-doctoral residencies
- **Osteopathic** internships and residencies
- **Medical** residencies: NRMP CaRMS
- **Pharmacy** practice residencies
- **Optometry** residencies
- **Medical Physics** residencies

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Matching Used In “Closed” Markets

- Applicant pool is clearly defined
- Recruiters are clearly defined
- Applicants start work/training at a common time
- Recruitment is very competitive

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Decision Makers

- Decision to implement usually rests with the recruiters
- Requires widespread participation – “75% rule”
- Sponsoring organization

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No Change Without Pain

- Recruiters need to recognize problems
  - Premature decisions on incomplete information
  - Offers moving earlier
  - Pressure tactics and unprofessional behavior
- Matching often perceived by recruiters as benefiting applicants more than recruiters
- Recruiters agree “for the benefit of the profession”

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Objections (1)

- Too impersonal
- Will lose control over recruitment decisions
- Inflexible, limits freedom of choice
- Will negatively affect number or quality of applicants

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Objections (2)

- Most-desirable recruiters don’t need it
- Least-desirable recruiters can’t compete
- Not everyone will play by the rules
- They are not like other professions
- Only works where too many / too few applicants

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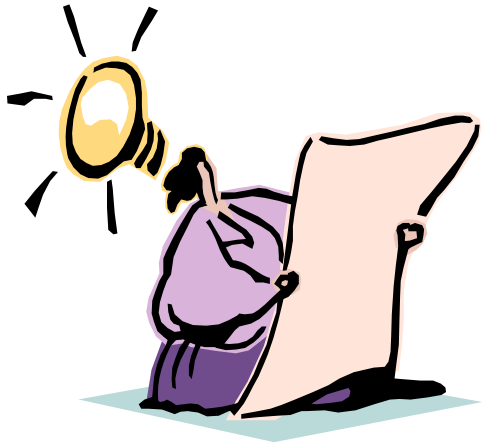
Education Program

- Many objections due to misunderstanding
- Need concerted education program
  - Initially
  - Ongoing



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Defining the Rules (1)

- Schedule of dates
- Funding mechanism
- Eligibility of applicants and recruiters
  - Verification of eligibility
- Rules for non-participants
- Communication of ranking intentions

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Defining the Rules (2)

- All positions in the match / no offers prior to the match
  - Exceptions?
- Match results are binding
  - Mechanism for release, enforcement
- Post-match process
- Availability of information

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Program Administration

- Infrastructure
  - Staff, systems
  - Educational program
  - Year-round activities, seasonal peaks
- Tailored to the needs of each profession
- Need for accuracy, fairness
  - “Protect people from themselves”

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Deferred Acceptance Algorithm (1)

- Simple procedure for clearing two-sided markets
- Recognized in 2012 Nobel prize in economics awarded to Lloyd Shapley and Alvin Roth
- Simulates what would happen if all participants act according to their stated preferences, and are not forced to make commitments before all offers are made

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Deferred Acceptance Algorithm (2)

- Recruiters make offers to their most preferred applicants
- Each applicant tentatively accepts the best offer received so far, rejects all less preferred offers, and waits for a better offer
- Each recruiter that receives a rejection makes an offer to the next most preferred applicant
- Process continues until there are no more rejections or offers to be made

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Important Features of Algorithm

- Produces stable result
  - No applicant/recruiter pair both prefer each other to their current match
- Strategy-proof
  - Best strategy for participants is to submit their true preferences

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Algorithm Implementation

- All our matches use the same algorithm software
- Roth-Peranson algorithm
  - Based on deferred acceptance
  - Applicant-proposing
  - Incorporates match “variations”

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Evolution of Algorithm

- Couples
- One applicant to multiple sequential positions
- Reversions
- Change to strictly applicant-proposing
- Limits from any one school
- Future – incorporate remuneration?

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Instabilities

- Consequence of match variations
  - Preferences may not be responsive and substitutable
- Three kinds of instabilities:
  1. Intrinsic
  2. Quasi-instability
  3. Systemic

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Intrinsic Instability

- No stable matching exists for the given set of preferences
- Unavoidable, “intrinsic” to the data
  - Not a function of algorithm implementation/programming
- Will cause algorithm to loop
  - Implementation must handle loops

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Quasi-Instability

- Result is “stable” according to the strict definition of stability, but ….
- Match result still appears to be “wrong” to some match participants

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Systemic Instability

- Stable matching exists but cannot be found
- May be caused by decisions made in implementation of algorithm
  - Sequencing
  - Attempt to avoid loops
  - Action taken when loop occurs

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Practical Considerations

- It may be easier to identify and correct systemic instabilities than to design and implement the programming to avoid the instability in the first place
  - Complexity of programming
  - Relative infrequency of instability
  - Availability of mechanisms to identify and correct instabilities

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Identifying Instabilities

- Instabilities are infrequent but inevitable
- Our system checks every match of every participant to identify instabilities (and errors)
- Need to be analyzed and addressed
  - Intrinsic instabilities may require selecting the "least offensive" result

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Correcting Instabilities

- Our system offers several approaches
  - Change input data
  - Modify results directly
  - Run algorithm in re-entrant mode
    - Automatically fixes some problems
  - Combination of techniques

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Complex Requirements

- Control mix of applicants with different characteristics
- Simple list of responsive rankings is inadequate
  - Non-substitutability of applicants
- Requirements differ among recruiters
- Applicants are indifferent to requirements

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Resolution

- Restate requirements as responsive lists that do not jeopardize stability
- Mechanisms / tools:
  - Submit multiple lists for one program
  - Assign priorities to lists
  - Revert positions between lists
- Addresses many (not all) requirements

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Example 1: A Specific Qualification

Preferences

		Bilingual
1	George	No
2	Mary	Yes
3	Greg	No
4	Sally	Yes
5	Ruth	No
6	Frank	No
7	Jane	No
8	Bob	Yes

Requirements

- 3 positions
- At least 1 bilingual
- More is acceptable
- Want Bob only if necessary as bilingual
- Prefer to have unfilled position if no bilingual match

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Example 1: A Specific Qualification

List A (Bilingual)
1 position

1 – Mary

2 – Sally

3 – Bob

List B
2 positions

1 – George

2 – Greg

3 – Sally

4 – Ruth

5 – Frank

6 – Jane

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Example 2: Variable Number of Positions

- Recruiter has 15 acceptable applicants
- Wants to match with 3 applicants
- Will take as many of the top 5 applicants as it can get

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Example 2: Variable Positions (cont.)

List A 5 positions	List B 0 positions	List C 0 positions
A1	A6	No Ranks
A2	A7	
A3	.	
A4	.	
A5	A15	

- First 2 unfilled from A revert to C
- Remainder of unfilled from A revert to B

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Example 3: Mix of Capabilities

- Prefer 1 applicant best suited for each age group of clients
  - Submit separate list for each age group
  - Create another “alternate” list that starts with 0 positions
- If one or more positions from separate lists do not fill, revert unfilled positions to the list of alternates

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Example 4: Reversion Pool

- Some low demand programs that may not fill and some high demand programs that could take more
  - Want to distribute unfilled positions from low demand to high demand programs with a specific priority, regardless of which positions don't fill
- Create a "reversion pool" to receive unfilled positions, and then redistribute them in appropriate manner

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Application of Techniques

- Accommodates most requirements
- Does have limitations
- Complex, difficult for users to understand
- Requires significant effort to make sure it is right
- Has been very successful

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Legal Issues

- Is a Matching Program legal?
  - Anti-trust law suit in U.S.
- Can participation be made mandatory?
- Is the use of multiple lists to achieve diversity legal?
- Can rules be enforced?

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Questions ?

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