

# How to Make Specialists NOT Specialised in TAC Market Design Competition? Behaviour-based Mechanism Design

Dengji Zhao<sup>1,2</sup>

Dongmo Zhang<sup>1</sup>    Laurent Perrussel<sup>2</sup>

<sup>1</sup>Intelligent Systems Laboratory  
University of Western Sydney, Australia

<sup>2</sup>IRIT, University of Toulouse, France

EC-Web 2011 - Aug 2011

# CAT Tournament

Trading Agent Competition Market Design (CAT Tournament, since 2007):

- a simulation of **double auction** markets, e.g. stock exchanges
- each participant/**specialist** designs and operates a double auction market
- traders (buyers and sellers) choose **profitable** markets to trade

How to win the game for a market/specialist:

- attracting more **traders**, i.e. higher market-share
- make more **transactions**
- gain more **profit**

# CAT Tournament

Trading Agent Competition Market Design (CAT Tournament, since 2007):

- a simulation of **double auction** markets, e.g. stock exchanges
- each participant/**specialist** designs and operates a double auction market
- traders (buyers and sellers) choose **profitable** markets to trade

**How to win the game for a market/specialist:**

- attracting more **traders**, i.e. higher market-share
- make more **transactions**
- gain more **profit**

# Challenges

- Traders have **different intelligence**.
  - markets don't know a trader's intelligence level
- Traders are **profit-driven**.
  - markets can lose a trader very easily, but hard to get it back
- You are not alone!
  - each market competes with one another

## So what?

A market performing very **well in one environment** might perform very **badly in another environment**.

# Challenges

- Traders have **different intelligence**.
  - markets don't know a trader's intelligence level
- Traders are **profit-driven**.
  - markets can lose a trader very easily, but hard to get it back
- You are not alone!
  - each market competes with one another

## So what?

A market performing very **well in one environment** might perform very **badly in another environment**.

# How to Solve It?

The goal (*reminder*):

- attracting more traders, i.e. higher market-share
- make more transactions
- gain more profit

## A Solution

Attracting more good traders and being adaptive.

## Questions

- How to distinguish good traders?
- How to attract them?

# Behaviour-based Mechanism Design

# How to Solve It?

The goal (*reminder*):

- attracting more traders, i.e. higher market-share
- make more transactions
- gain more profit

## A Solution

Attracting more good traders and being adaptive.

## Questions

- How to distinguish good traders?
- How to attract them?

# Behaviour-based Mechanism Design

# How to Solve It?

The goal (*reminder*):

- attracting more traders, i.e. higher market-share
- make more transactions
- gain more profit

## A Solution

Attracting more good traders and being adaptive.

## Questions

- How to distinguish good traders?
- How to attract them?

Behaviour-based Mechanism Design



# How to Solve It?

The goal (*reminder*):

- attracting more traders, i.e. higher market-share
- make more transactions
- gain more profit

## A Solution

Attracting more good traders and being adaptive.

## Questions

- How to distinguish good traders?
- How to attract them?

# Behaviour-based Mechanism Design

# Outline

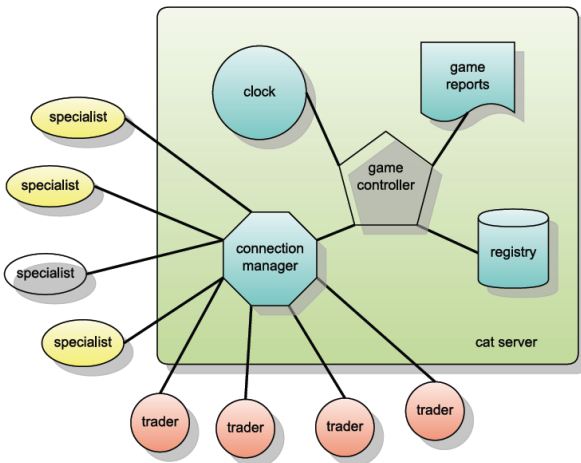
- 1 Background
  - CAT Platform
- 2 Behaviour-based Trader Classification
  - Defining Categories of Trader
  - Category Recognition from Behaviour
- 3 Behaviour-based Policy Design
  - Defining Design Space
  - Trader-dependent Mechanism Design
  - Combining Trader-dependent Mechanisms
- 4 Evaluation
  - Experiments
  - CAT Competitions
- 5 Conclusion

# Outline

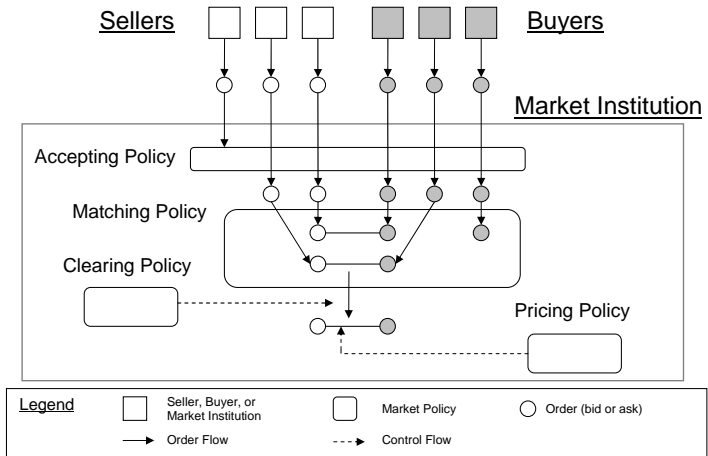
- 1 Background
  - CAT Platform
- 2 Behaviour-based Trader Classification
- 3 Behaviour-based Policy Design
- 4 Evaluation
- 5 Conclusion

# Overall Structure

Trading Agent Competition Market Design (CAT) Platform:



# Structure of Specialists/Markets



# Structure of Traders

Each trader has:

- 1 a **private valuation** of the commodity
- 2 number of commodities to trade in each day
- 3 two strategies

The two strategies:

- 1 market selection strategy
  - determines which market to trade, e.g. always choose the most profitable one
- 2 bidding strategy, e.g. ZIC, ZIP, GD and RE
  - determines a bidding price for each order

# Structure of Traders

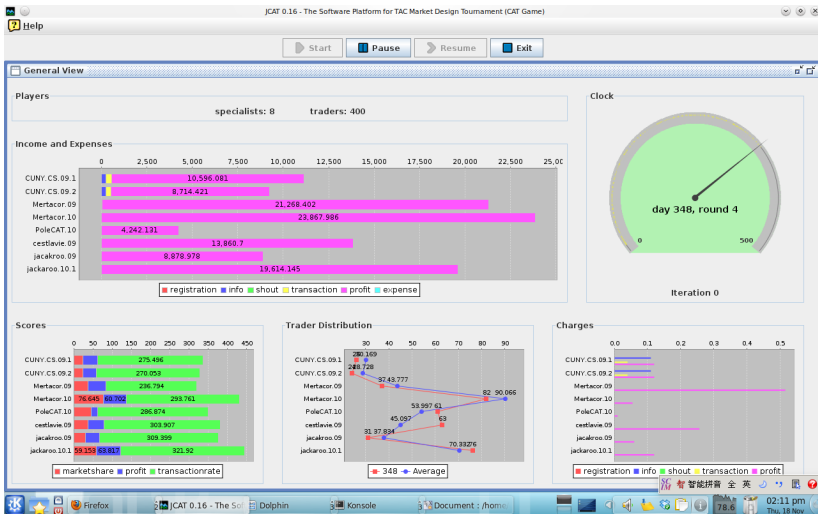
Each trader has:

- 1 a **private valuation** of the commodity
- 2 number of commodities to trade in each day
- 3 two strategies

## The two strategies:

- 1 market selection strategy
  - determines which market to trade, e.g. always choose the most profitable one
- 2 bidding strategy, e.g. ZIC, ZIP, GD and RE
  - determines a bidding price for each order

# A Snapshot





# Outline

- 1 Background
- 2 Behaviour-based Trader Classification
  - Defining Categories of Trader
  - Category Recognition from Behaviour
- 3 Behaviour-based Policy Design
- 4 Evaluation
- 5 Conclusion

# What Kind of Traders are Attractive?

Given the perfect **equilibrium price**  $p_e^*$  of a market, we say a trader  $i$  is

- attractive (**intra-marginal**): if trader  $i$ 's private valuation  $v_i \leq p_e^*$  ( $v_i \geq p_e^*$ )
- not attractive (**extra-marginal**): otherwise.

# What Kind of Traders are Attractive?

Given the perfect **equilibrium price**  $p_e^*$  of a market, we say a trader  $i$  is

- attractive (**intra-marginal**): if trader  $i$ 's private valuation  $v_i \leq p_e^*$  ( $v_i \geq p_e^*$ )
- not attractive (**extra-marginal**): otherwise.

## Question

$p_e^*$  and  $v_i$  are **unknown** to all markets, how to recognize attractive traders?

# By Utilizing Their Behaviour

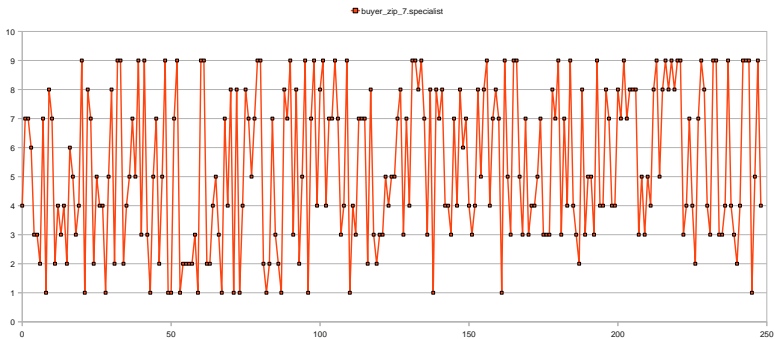
We can get from a trader's limited trading history:

- trading time distribution
- average transaction price
- ...

Category Recognition from Behaviour

# Trading Time Distribution

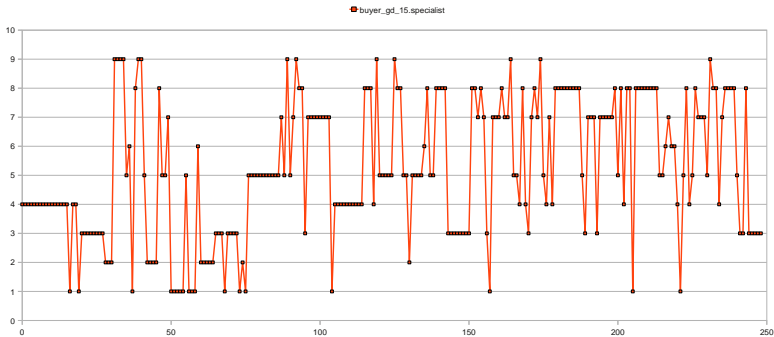
Very unstable trader



Category Recognition from Behaviour

# Trading Time Distribution

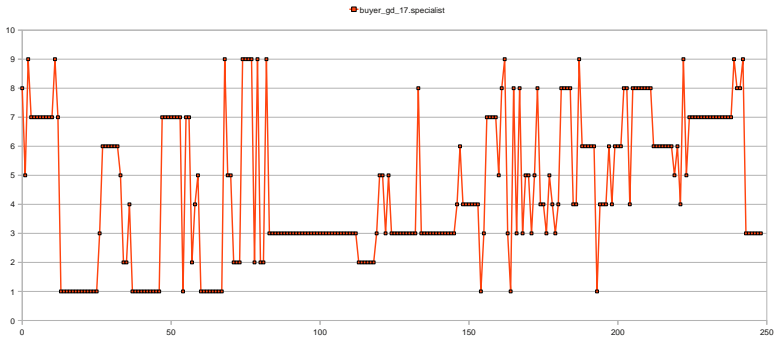
## Unstable stable trader



Category Recognition from Behaviour

# Trading Time Distribution

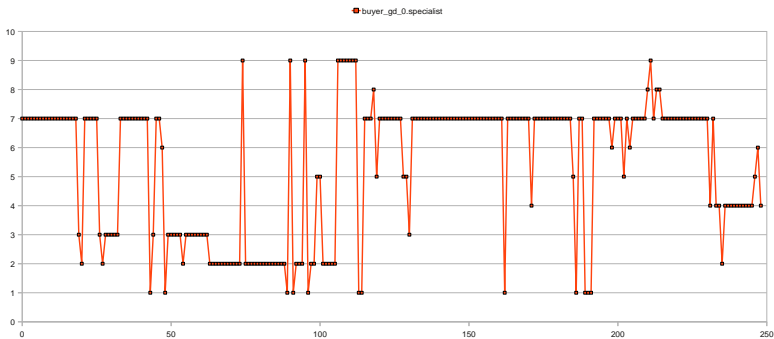
## Stable trader



Category Recognition from Behaviour

# Trading Time Distribution

Very stable trader

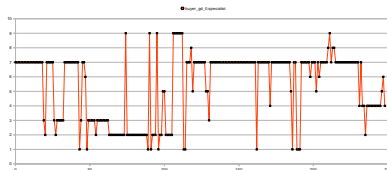
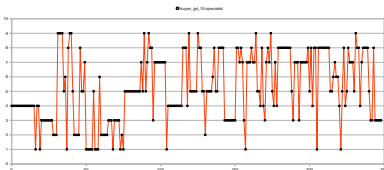
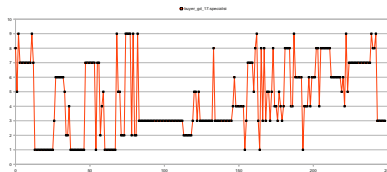
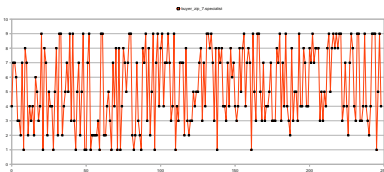




Category Recognition from Behaviour

# Trading Time Distribution

Attract stable traders



# We Know What Kind of Traders to Attract, Then...

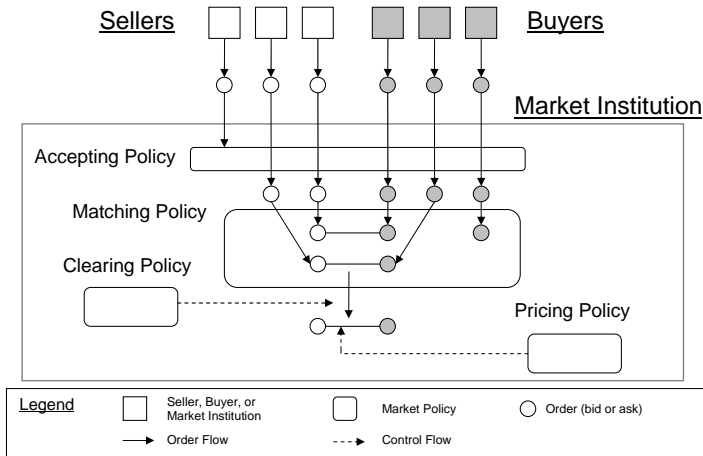
## Question

How to attract them?

# Outline

- 1 Background
- 2 Behaviour-based Trader Classification
- 3 Behaviour-based Policy Design**
  - Defining Design Space
  - Trader-dependent Mechanism Design
  - Combining Trader-dependent Mechanisms
- 4 Evaluation
- 5 Conclusion

# Policies of Specialist



# Accepting Policy

Highest Acceptable Ask Price



Equilibrium Price



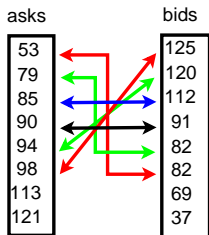
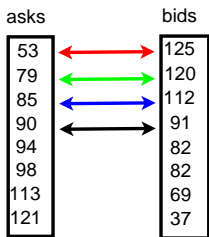
Lowest Acceptable Bid Price

# Matching Policy

Two most commonly used matching policies:

- equilibrium matching
- maximal matching

# Equilibrium Matching vs Maximal Matching



- 1 profit maximizing
- 2 can have more transactions

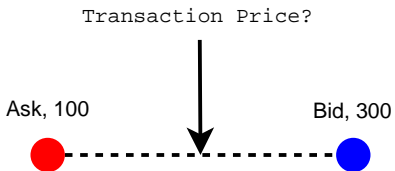
- 1 not profit maximizing
- 2 transaction maximizing

# Behaviour-based Matching Policy

- **double** equilibrium matching
- **behaviour-based** maximal matching



# Pricing Policy



# Mechanism Design in Specific Enviroments

---

**Input:**  $m_0$ : initial mechanism,  $f_m$ : a function of mechanism to maximise,  $\delta$ : the minimum improvement

**Output:**  $m^*$ : the local best mechanism

```

1 begin
2    $CurrBest \leftarrow m_0$ ;
3   repeat
4      $m^* \leftarrow CurrBest$ ;
5     foreach policy parameter  $r$  do
6        $m' \leftarrow$  monotonically update  $r$  in  $m^*$ ;
7       if  $f_m(m') > f_m(CurrBest)$  then  $CurrBest \leftarrow m'$ ;
8     end
9   until  $f_m(CurrBest) < f_m(m^*) + \delta$ ;
10 end
  
```

---

# Why Do We Need Trader-dependent Mechanisms?

	Specialists								StdDev
	Cu09.1	Cu09.2	Me09	Me10	Po10	Ce09	Ja09	JaGD	
ZIC Sellers	39.60	40.40	54.20	<b>136.27</b>	56.83	55.07	42.87	74.77	31.95
ZIC Buyers	41.77	36.13	46.23	<b>125.53</b>	67.13	53.93	46.17	83.10	29.64
ZIP Sellers	15.43	16.77	50.00	<b>179.20</b>	62.50	50.83	<u>59.40</u>	65.87	51.04
ZIP Buyers	18.30	21.07	49.00	<b>197.83</b>	64.50	40.90	45.37	63.03	57.24
GD Sellers	20.73	22.46	49.29	<u>77.80</u>	<u>87.43</u>	62.37	37.84	<b>142.09</b>	40.21
GD Buyers	22.91	19.57	51.23	69.50	79.84	<u>69.66</u>	41.34	<b>145.94</b>	40.26
RE Sellers	53.10	47.31	53.59	<b>89.76</b>	69.46	<u>67.90</u>	55.91	62.97	13.43
RE Buyers	<u>55.19</u>	<u>51.56</u>	<u>55.61</u>	<b>86.56</b>	73.07	64.94	55.07	58.00	11.91

# From Trader-dependent to Trader-independent

- **Dynamically** combine/select trader-dependent mechanisms according to **online** market environment.

# Outline

- 1 Background
- 2 Behaviour-based Trader Classification
- 3 Behaviour-based Policy Design
- 4 Evaluation**
  - Experiments
  - CAT Competitions
- 5 Conclusion

# Example: GD Attractive Mechanism

Specialists									Standard Deviation
Cu09.1	Cu09.2	Me09	Me10	Po10	Ce09	Ja09	JaGD		
<i>intra-marginal buyers (with valuations between 160 and 110)</i>									
ZIC	27.60	17.27	34.13	<b>181.27</b>	65.27	46.20	36.73	91.53	53.39
ZIP	18.70	20.85	42.10	<b>256.15</b>	58.85	27.40	40.90	35.05	79.31
GD	23.97	18.64	36.72	70.92	75.42	64.81	18.53	<b>191.00</b>	57.02
RE	42.53	39.88	48.84	<b>113.66</b>	82.91	68.22	47.84	56.13	25.12
<i>lower extra-marginal buyers (with valuations between 110 and 90)</i>									
ZIC	48.25	49.38	56.13	79.38	71.88	58.75	50.38	<b>85.88</b>	14.62
ZIP	16.60	23.40	46.00	89.80	71.80	60.20	34.20	<b>158.00</b>	45.77
GD	28.44	21.44	38.89	47.67	108.89	65.22	33.56	<b>155.89</b>	46.81
RE	68.86	57.86	55.14	66.00	<b>70.29</b>	62.71	59.14	60.00	5.43
<i>other extra-marginal buyers (with valuations between 90 and 60)</i>									
ZIC	64.71	61.43	60.86	58.86	<b>65.71</b>	65.00	61.57	61.86	2.39
ZIP	18.40	19.60	79.60	72.60	<b>79.80</b>	75.60	74.40	80.00	26.99
GD	19.40	20.24	76.56	75.32	75.76	<b>78.24</b>	77.00	77.48	26.36
RE	<b>65.16</b>	62.19	62.71	63.23	63.55	62.06	61.61	59.48	1.64

# Our CAT Specialist: *jackaroo*

*jackaroo* achievements:

- CAT 2007: 4th
- CAT 2008: 3rd
- CAT 2009: 1st
- CAT 2010: 2nd
- **CAT 2011: 1st**

# CAT 2011

## Basic settings:

- 400 traders, 3 items to trade in each day.
- 5 teams/specialists
- three final games, each game lasts 500 virtual days.

## Traders' bidding strategy distribution:

- Game 1: 120 GDs, 100 ZIPs, 120 REs and 60 ZICs.
- Game 2: 120 GDs, 80 ZIPs, 150 REs and 50 ZICs.
- Game 3: 160 GDs, 60 ZIPs, 140 REs and 40 ZICs.



# CAT 2011 Results

## jackaroo, PoleCAT and Mertacor:

- Game 1: 120 GDs, 100 ZIPs, 120 REs and 60 ZICs.
  - **251.396** (242.094, 216.103):
    - market-share: **119.173** (106.248, **120.008**)
    - transaction rate: **469.089** (405.873, 429.494)
    - profit: **165.901** (**214.145**, 98.798) *[0.031,0.149,0.033]*
- Game 2: 120 GDs, 80 ZIPs, 150 REs and 50 ZICs.
- Game 3: 160 GDs, 60 ZIPs, 140 REs and 40 ZICs.

# CAT 2011 Results

## jackaroo, PoleCAT and Mertacor:

- Game 1: 120 GDs, 100 ZIPs, 120 REs and 60 ZICs.
  - **251.396** (242.094, 216.103):
    - market-share: **119.173** (106.248, **120.008**)
    - transaction rate: **469.089** (405.873, 429.494)
    - profit: **165.901** (**214.145**, 98.798) *[0.031,0.149,0.033]*
- Game 2: 120 GDs, 80 ZIPs, 150 REs and 50 ZICs.
  - **226.056** (216.234, 215.95):
    - market-share: **104.581** (103.014, **109.206**)
    - transaction rate: **463.772** (390.146, 421.937)
    - profit: **109.8** (**155.537**, 116.731) *[0.03,0.145,0.03]*
- Game 3: 160 GDs, 60 ZIPs, 140 REs and 40 ZICs.

# CAT 2011 Results

## jackaroo, PoleCAT and Mertacor:

- Game 1: 120 GDs, 100 ZIPs, 120 REs and 60 ZICs.
  - **251.396** (242.094, 216.103):
    - market-share: **119.173** (106.248, **120.008**)
    - transaction rate: **469.089** (405.873, 429.494)
    - profit: **165.901** (**214.145**, 98.798) *[0.031,0.149,0.033]*
  - Game 2: 120 GDs, 80 ZIPs, 150 REs and 50 ZICs.
    - **226.056** (216.234, 215.95):
      - market-share: **104.581** (103.014, **109.206**)
      - transaction rate: **463.772** (390.146, 421.937)
      - profit: **109.8** (**155.537**, 116.731) *[0.03,0.145,0.03]*
    - Game 3: 160 GDs, 60 ZIPs, 140 REs and 40 ZICs.
      - **207.759** (**221.798**, 210.426):
        - market-share: **112.333** (100.75, 98.341)
        - transaction rate: **444.394** (397.434, 379.493)
        - profit: **66.52** (**167.251**, 153.481) *[0.032,0.147,0.093]*

# Outline

- 1 Background
- 2 Behaviour-based Trader Classification
- 3 Behaviour-based Policy Design
- 4 Evaluation
- 5 Conclusion**

# Summary

We have proposed a framework for **behaviour-based mechanism design** which consists of:

- behaviour-based trader classification
- behaviour-based policy design
- searching trader-dependent mechanisms
- integrating trader-dependent mechanisms online

**What we can improve in the future:**

- better trader classification
- build clearer relationship between loosely coupled policies

# Summary

We have proposed a framework for **behaviour-based mechanism design** which consists of:

- behaviour-based trader classification
- behaviour-based policy design
- searching trader-dependent mechanisms
- integrating trader-dependent mechanisms online

**What we can improve in the future:**

- better trader classification
- build clearer relationship between loosely coupled policies

# Acknowledgments

- **People:** Dongmo Zhang, Laurent Perrussel, *jackaroo* team, and anonymous reviewers.
- **Funding:** the Australian Research Council Discovery Project DP0988750.

# Acknowledgments

- **People:** Dongmo Zhang, Laurent Perrussel, *jackaroo* team, and anonymous reviewers.
- **Funding:** the Australian Research Council Discovery Project DP0988750.

**Thank you for your attention!**



Welcome!

**Welcome to Toulouse!**

Welcome!

**Welcome to Toulouse!**  
**Welcome to join CAT games!**