Contents

Al	Abstract									
Ac	Acknowledgments									
1	Intr	oduction	1							
	1.1	Background	1							
	1.2	Problem Statement	3							
	1.3	Research Objectives	5							
	1.4	Research Route and Thesis Structure	6							
2	Rela	ated Works 1	0							
	2.1	Chapter Introduction	.0							
	2.2	Game and Uncertainty	.0							
	2.3	Player Experience and Entertainment	.3							
	2.4	Motion in Mind	7							
		2.4.1 Game Refinement Theory	18							
		2.4.2 Physics in Mind	19							
	2.5	Chapter Conclusion	27							
3	Uno	certainty under Different Settings 2	28							
	3.1	Chapter Introduction	28							
	3.2	Game Test-beds	31							
	3.3	Assessment Methods Employed for DouDiZhu	32							
	3.4	Game Simulation and Data Collection	34							
		3.4.1 Simulation Setups	35							
		3.4.2 Experiment on the Classic DouDiZhu	39							
		3.4.3 Comparison with the Variants of DouDiZhu Game in China	42							
	3.5	Comparisons with other game	47							

		3.5.1	Other Popular Shedding-type Card Games	47			
		3.5.2	Why DouDiZhu is the Most Popular Card Game in China?	49			
	3.6	Chapt	er Conclusion	52			
4	Uno	certain	ty Dynamics in Game Process	53			
	4.1	Chapt	er Introduction	53			
	4.2	Game	Test-beds	54			
		4.2.1	Flappy Bird	55			
		4.2.2	Classic Tetris	57			
		4.2.3	Pong	58			
		4.2.4	Brick Car Racing	59			
	4.3	Motion	n in Mind for Single Agent Games	60			
		4.3.1	Relative Velocity	60			
		4.3.2	Resultant Force	61			
		4.3.3	Jerk as the measure of "Suprise" $\ \ldots \ \ldots \ \ldots \ \ldots$	62			
	4.4	Data (Collection and Analysis	63			
		4.4.1	Experiment and Environment Setting	64			
		4.4.2	Evaluation Metric via Growth Rate	64			
		4.4.3	Analysis of General Game Process Dynamic	65			
		4.4.4	Analysis of In-Game Process	70			
	4.5	Chapter Conclusion					
5	Lon	ıg Tern	n Uncertainty with Little Interaction	77			
			er Introduction	77			
	5.2						
	5.3	3 Game Test-beds					
		5.3.1	Cookie Clicker	82			
		5.3.2	AdVenture Capitalist	83			
		5.3.3	Clicker Heroes	84			
	5.4	Data (Collection and Analysis	85			
		5.4.1	The sequential growth rate in idle games	85			
		5.4.2	Motion in Mind of Idle Games	86			

		5.4.3	Mechanism of Idle Games	. 91					
	5.5	ssion	. 94						
		5.5.1	Prestige as jerk in idle games	. 94					
		5.5.2	Universal Gravitation in Games	. 95					
	5.6 Chapter Conclusion								
				99					
6 Conclusion									
	6.1	Genera	al Discussion of Uncertainty in Games	. 99					
	6.2	Answe	ers to Research Questions	. 104					
	6.3	Conclu	uding Remark	. 105					
Pι	ıblica	ations		120					

List of Figures

1.1	Research route of the thesis. The games from left to right are respectively	
	the card game DouDiZhu; single player arcade game Flappy Bird, Tetris,	
	Pong, and Brick car racing; idle game Cookie Clicker, Adventure Capitalist,	
	and Clicker Hero	7
2.1	Maslow's motivation model	14
2.2	Paradigm of flow state in theory and in reality	16
2.3	Conceptual model of engagement and addiction as a transition from base-	
	line states (normal or flow states) in game-playing based on the prioriti-	
	zation (ordering, highest to lowest) and intensity $(+ = \text{high}, - = \text{low})$ of	
	control, focus, and motives (C, F, M) [1]	17
2.4	A model of move selection in most games [2]	22
2.5	A model of move selection for arcade games experts	22
2.6	Illustration of law of motion in mind over various mass. $\vec{p_2}$ is derived based	
	on the conservation of E_p , which provided two peaks of profit-winning	
	engagement $(m = \frac{3+\sqrt{3}}{6})$ and risk-taking engagement $(m = \frac{3-\sqrt{3}}{6})$	26
3.1	A screenshot of the Happy DouDiZhu game	30
3.2	Game information process: certainty of outcome	33
3.3	Stages of classical DouDiZhu	34
3.4	Download ranking adopted from the web article	50
3.5	The depiction of game refinement values of the well-refined games men-	
	tioned in the study	5]
4.1	Screenshot of target arcade games	55
4.2	Google trend interest of "Flappy Bird" over time	56
43	How practice affected score of Flappy Bird	57

4.4	Various measures of motion in mind, where the objective (in-game) is de-	
	picted based on solid lines and subjective recognition (in mind) is depicted	
	based on dashed line. Also, the dotted line represent the relative velocity	
	and resultant force measures	62
4.5	Schematic diagram of milestone measure in the arcade games context $\ . \ . \ .$	65
4.6	Growth rate of four different arcade games (a) Flappy bird, (b) Pong, (c)	
	Tetris, and (d) Brick Car Racing. Green lines designates the record score	
	for each game, while orange lines designates the milestone reached so far. $$.	66
4.7	Motion in mind for arcade games	68
4.8	Milestone process for game brick car racing (BC), Pong (PN), Flappy Bird	
	(FB), and Tetris (TR). Forward game and backward game concepts are	
	proposed by Kita et al. focusing on the logistics model of game-outcome	
	uncertainty [3]	69
4.9	The acceleration (a) and jerkiness (j) of four different arcade games (a)Flappy	
	bird, (b)Pong, (c)Tetris, and (d) Brick Car Racing	71
4.10	The dynamic of velocity (v) in Flappy Bird (FB) and Pong (PN) game $$	72
4.11	The dynamic of velocity (v) of Brick Car Racing (BC) and Tetris (TR) game	73
4.12	The jerk dynamics of the players in (a) 2019 and (b) 2020 Final for Classic	
	World Championship	74
5.1	Various measures of motion in mind, where the objective (in-game) is de-	
	picted based on solid lines and subjective recognition (in mind) is depicted	
	based on dashed line. When m=0.5, the point $\vec{p_2}=0$, $E_p=E_q=\vec{p_1}$, and	
	${\cal E}$ reaches its peak. It indicates at this state, the game-playing would pro-	
	cess without any influence from the engagement experience thus expected	
	to have the greatest attractiveness	80
5.2	Screenshot of Cookie Clicker	82
5.3	Official promotional poster for the Adventure Capitalist	83
5.4	Promotional poster for the Clicker Heroes on Steam	84
5.5	Function curve diagram of holy trinity of idle game math design	86
5.6	Various measures of motion in mind for idle games	87
5.7	Various derivatives of measures of motion in mind for idle games	89

5.8	Various second derivatives of measures of motion in mind for idle games	90
5.9	Prestige loops in idle games	91
5.10	Schematic diagram of prestige comparison in the idle games, with only one	
	generator. Though it will be slight different with real play, progression	
	is similar. Calculation is based on Equation 5.4 and Equation 5.3. The	
	$income_{base}$ is set as 20, and the $cost_{base}$ is 4, and growth rate is 1.11. And	
	we assume when a player gains 30% of prestige currency, they will gain a	
	new prestige in the game	92
5.11	Information dynamics in idle games with respect to jerk in mind when	
	prestige	93
5.12	Engagement model [4]	96
6.1	Motion in mind of all the targets	103

List of Tables

2.1	Measure (GR) of game remement for some popular games [5]	19
2.2	Analogical link between physics and game (adopted from $[6]$)	25
3.1	Numerical value of the considered card categories in the simulation \dots	36
3.2	Categories of Cards	39
3.3	Measures of game refinement for classical DouDiZhu	40
3.4	Possible scores of landlord and peasant with different card distribution	
	settings	41
3.5	The results of simulation performed using different DouDiZhu AIs for var-	
	ious game settings	41
3.6	Scores using different DouDiZhu AIs of DDZ[(3,1,2) (20.17.17)]	42
3.7	Versions of DouDiZhu games	43
3.8	Measures of game refinement for two variants of DouDiZhu	43
3.9	Possible scores of landlord and peasant in different game settings	44
3.10	The results of simulation performed using different DouDiZhu AIs for var-	
	ious game settings	45
3.11	Pass frequency of different level DouDiZhu AIs: comparing classical DoudiZhu	
	and four-players DouDiZhu setting	46
3.12	Justification results of different levels of AI and human players	46
3.13	Popular shedding-type card games from different regions	48
3.14	DouDiZhu similar card games over the world	49
3.15	Comparison of some well-refined board and card games in China (ordered	
	by decreasing GR value)	50
4.1	Information for the chosen players	73
4.2	Analysis of Jerk for the chosen players	75
5.1	The sequential growth rate and physics parameters of idle games	87
5.2	Analogical link between gravitation in physics and mind	97

6.1	Motion i	n mind	for all	the	e events mentioned in this thesis	00
0.1	TITO (TOIL I	TT TITITICE	TOT CCIT	(11)	c cyclus memioned in this thesis	11/