

# Exam

● Graded

Student

Boxiang Fu

Total Points

81 / 100 pts

Question 1

(no title)

4 / 4 pts

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

✓ - 0 pts Correct

Question 2

(no title)

4 / 4 pts

✓ - 0 pts Correct

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 3

(no title)

2 / 4 pts

- 0 pts Correct

✓ - 1 pt A

✓ - 1 pt B

- 1 pt C

- 1 pt D

Question 4

(no title)

2 / 4 pts

– 0 pts Correct

– 1 pt A

– 1 pt B

✓ – 1 pt C

✓ – 1 pt D

Question 5

(no title)

4 / 4 pts

✓ – 0 pts Correct

– 1 pt A

– 1 pt B

– 1 pt C

– 1 pt D

Question 6

(no title)

3 / 4 pts

– 0 pts Correct

– 1 pt A

✓ – 1 pt B

– 1 pt C

– 1 pt D

Question 7

(no title)

3 / 4 pts

– 0 pts Correct

✓ – 1 pt A

– 1 pt B

– 1 pt C

– 1 pt D

Question 8

(no title)

2 / 4 pts

– 0 pts Correct

– 1 pt A

✓ – 1 pt B

– 1 pt C

✓ – 1 pt D

Question 9

(no title)

4 / 4 pts

✓ – 0 pts Correct

– 1 pt A

– 1 pt B

– 1 pt C

– 1 pt D

Question 10

(no title)

4 / 4 pts

✓ – 0 pts Correct

– 1 pt A

– 1 pt B

– 1 pt C

– 1 pt D

Question 11

(no title)

3 / 4 pts

– 0 pts Correct

– 1 pt A

– 1 pt B

✓ – 1 pt C

– 1 pt D

Question 12

(no title)

4 / 4 pts

✓ - 0 pts Correct

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 13

(no title)

3 / 4 pts

- 0 pts Correct

- 1 pt A

✓ - 1 pt B

- 1 pt C

- 1 pt D

Question 14

(no title)

3 / 4 pts

- 0 pts Correct

✓ - 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 15

(no title)

3 / 4 pts

- 0 pts Correct

✓ - 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 16

(no title)

2 / 4 pts

– 0 pts Correct

– 1 pt A

– 1 pt B

✓ – 1 pt C

✓ – 1 pt D

Question 17

(no title)

3 / 4 pts

– 0 pts Correct

– 1 pt A

– 1 pt B

✓ – 1 pt C

– 1 pt D

Question 18

(no title)

3 / 4 pts

– 0 pts Correct

✓ – 1 pt A

– 1 pt B

– 1 pt C

– 1 pt D

Question 19

(no title)

3 / 4 pts

– 0 pts Correct

– 1 pt A

✓ – 1 pt B

– 1 pt C

– 1 pt D

Question 20

(no title)

4 / 4 pts

✓ - 0 pts Correct

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 21

(no title)

3 / 4 pts

- 0 pts Correct

✓ - 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 22

(no title)

4 / 4 pts

✓ - 0 pts Correct

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 23

(no title)

4 / 4 pts

✓ - 0 pts Correct

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 24

(no title)

4 / 4 pts

✓ - 0 pts Correct

- 1 pt A

- 1 pt B

- 1 pt C

- 1 pt D

Question 25

(no title)

3 / 4 pts

- 0 pts Correct

- 1 pt A

✓ - 1 pt B

- 1 pt C

- 1 pt D

Boxiang Fu  
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## CS 15-888 Computational Game Solving: Final Exam

**Instructions:** The total number of points possible is 100. Each question is worth 4 points. Each question has *one or more* correct answers, and you must select all of them to receive full credit. For each subquestion, getting it right yields 1 point and getting it wrong yields 0 points.

1. Consider a sequential game with perfect information. Which of the following statements are true?

- ☒ A) Backward induction always gives a subgame perfect equilibrium  
☒ B) There exists a pure Nash equilibrium  
☐ C) Every Nash equilibrium is subgame perfect  
☒ D) Every subgame perfect equilibrium is a Nash equilibrium

2. The minmax theorem for 2-player  $n$ -action 0-sum normal-form games was proven by

- A) Emile Borel  
☒ B) John von Neumann  
☐ C) John Nash  
☐ D) Harold Kuhn

3. Consider a two-player zero-sum game in which the utilities of the row player are given by the following table.

	$p_1$	$p_2$	$1-p_1-p_2$
	A	B	C
A	0	-2	1
B	2	0	-1
C	-1	1	0

Which of the following strategies is in the set of maxmin strategies for the row player?

- A) (0.25, 0.25, 0.5)  
☒ B) (0.25, 0.5, 0.25)  
☐ C) (1/3, 1/3, 1/3)  
☒ D) (0.5, 0.25, 0.25)

Column P:  
 A B C  
 BR B C A  
 Ex in exp:

$$0.25(-2p_2 + 1 - p_1 - p_2) = 0.25(2p_1 - 1 + p_1 + p_2) = 0.25(-p_1 + p_2)$$

4. Consider the two-player general-sum game

	A	B
A	(3, 2)	(0, 0)
B	(0, 0)	(2, 3)

How many Nash equilibria does this game have?

- A) 1  
 B) 2  
 C) 3  
☒ D) Infinitely many
5. Consider a two-player zero-sum game in which the utilities of the row player are given by the following table.

	A	B	C	D	E	F	G	H	I	J
A	0	1	-2	0	3	-1	2	-3	1	0
B	-1	0	2	-1	0	1	-2	2	-1	3
C	2	-2	0	1	-1	0	2	-2	0	-1
D	0	1	-1	0	2	-2	1	0	-1	2
E	-3	0	1	-2	0	1	-3	2	0	-2
F	1	-1	0	2	-1	0	0	1	-2	1
G	-2	2	-2	-1	3	0	0	-1	2	0
H	3	-2	2	0	-2	-1	1	0	-1	2
I	-1	1	0	1	0	2	-2	1	0	-2
J	0	-3	1	-2	2	-1	0	-2	2	0

What is the value of this game?

- A) -1  
 B) 0.5  
 C) 1  
☒ D) 0
6. Which of the following is guaranteed to converge to the set of minimax equilibria in two-player zero-sum games?
- A) Last iterate of fictitious play  
 B) Average iterate of fictitious play  
☒ C) Average iterate of regret matching<sup>+</sup>  
 D) Average iterate of best-response dynamics
7. Which of the following statements are true for normal-form games?

- A) A Nash equilibrium can be supported on weakly dominated actions
- B) A correlated equilibrium can be supported on strictly dominated actions
- ☒ C) A coarse correlated equilibrium can be supported on strictly dominated actions
- D) If a player has a strictly dominant action  $a$ , a coarse correlated equilibrium can be supported on an action  $a' \neq a$

8. Which of the following solution concepts supports polynomial-time strategy finding in adversarial team games?

- A) Team maximin equilibrium (TME)
- ☒ B) Team maximin equilibrium with coordination device (TMECor)
- C) Nash equilibrium that minimizes the utility of the adversary
- D) Coarse correlated equilibrium

9. Which of the following algorithms is the most efficient in terms of per-iteration running time?

- A) CFR
- ☒ B) Outcome-sampling MCCFR
- C) External-sampling MCCFR
- D) Fictitious play

CFR	CCE
$\frac{1}{0.5}$	$\frac{1}{0}$
2	$\infty$

10. The *price of anarchy*  $PoA_E$  of a game with respect to a solution concept  $E$  is defined as the ratio between the maximum attainable social welfare in the game and the welfare of the *worst-case* equilibrium from the set  $E$ . (The game is assumed to have nonnegative utilities.) The *price of stability*  $PoS_E$  is the ratio between the maximum attainable social welfare and the welfare of the *best-case* equilibrium from  $E$ . Which of the following statement(s) holds?

- ☒ A)  $PoA_{NE} \leq PoA_{CCE}$
- B)  $PoA_{CCE} \leq PoA_{CE}$
- C)  $PoS_{NE} \leq PoS_{CCE}$
- ☒ D)  $PoS_{CCE} \leq PoS_{CE}$



11. Which of the following is an advantage of the sequence-form representation over behavioral strategies?

- A) It uses less memory
- B) It is as expressive as mixed strategies in both imperfect- and perfect-recall games
- ☒ C) It is as expressive as mixed strategies in perfect-recall games
- ☒ D) The utility is linear in that player's strategy when the rest of the players are fixed

12. Which of the following statements are true?

- ☒ A) CE allows deviating after observing the recommendation; CCE only before  
☐ B) In a zero-sum game, the marginals of any CCE constitute a Nash equilibrium  
☐ C) In a zero-sum game, the marginals of any CE constitute a Nash equilibrium  
☐ D) CCE allows deviating after observing the recommendation; CE only before
13. A pair of strategies  $(x, y)$  is symmetric if  $x = y$ . A correlated distribution  $\mu$  is symmetric if  $\mu_{ij} = \mu_{ji}$ . Consider a symmetric two-player game  $(A, A^T)$ . Which of the following statement(s) is true?
- ☒ A) There is always a symmetric Nash equilibrium  
☐ B) All Nash equilibria are symmetric  
☐ C) Running simultaneous regret matching<sup>+</sup> produces a correlated distribution that is in the limit a symmetric coarse correlated equilibrium  
☒ D) Running simultaneous regret matching produces a correlated distribution that is in the limit a symmetric coarse correlated equilibrium
14. Which of the following is true about the regret matching algorithm?
- ☐ A) When employed by all players, the correlated distribution of play converges to a coarse correlated equilibrium in general-sum games  
☐ B) When employed by all players, it converges to a Nash equilibrium in general-sum games  
☒ C) It guarantees sublinear external regret against an adversary  
☐ D) When employed by all players, the correlated distribution of play converges to a welfare-maximizing coarse correlated equilibrium in two-player games
15. Which of the following statements are true for the sequence-form polytope?
- ☐ A) The number of vertices can be exponential in the dimension  
☒ B) It can be described with a number of constraints that is polynomial in the dimension  
☒ C) Given a point, there is a polynomial-time algorithm that ascertains whether that point belongs in the sequence-form polytope  
☒ D) It is a bounded set
16. Which of the following algorithms can strictly increase exploitability in a zero-sum game from one iteration to the next?
- ☐ A) Anytime double oracle  
☒ B) Double oracle  
☐ C) Last iterate of best-response dynamics  
☐ D) Last iterate of regret matching

17. Which of the following statements are true about Deep CFR?

- ☒ A) It uses neural networks to approximate the counterfactual regrets at each information set
- ☐ B) It is guaranteed to converge to optimal strategies in imperfect-recall games
- ☐ C) It obviates the need for manual game abstraction
- ☒ D) It relies on MCCFR

18. Which of the following statements are true?

- ☐ A) Executing the Blum-Mansour algorithm for minimizing swap regret in extensive-form games requires exponential time
- ☒ B) There are online algorithms with zero external regret but swap regret growing linearly in the time horizon
- ☐ C) Swap regret minimization guarantees convergence to a Nash equilibrium in general-sum games
- ☒ D) Swap regret minimization guarantees time-average convergence to a Nash equilibrium in two-player zero-sum games

19. Which of the following statements are true concerning abstraction in two-player zero-sum games?

- ☐ A) Computing an equilibrium in a coarser abstraction will always result in greater exploitability
- ☐ B) If abstraction is performed only with respect to the maximizing player, a max-min strategy in a finer abstraction can only be closer to the value of the game
- ☒ C) Lossless abstraction can result in a game with the same number of nodes
- ☒ D) The value of a game is equal to the value of a lossless abstraction thereof

20. Which of the following statements are true concerning optimistic no-regret algorithms?

- ☐ A) Their per-iteration running time is lower than their non-optimistic counterparts
- ☒ B) They rely on a prediction vector
- ☐ C) They converge to Nash equilibria in two-player general-sum games
- ☐ D) They can guarantee  $o(\sqrt{T})$  regret against an adversary

21. Which of the following online algorithms are equivalent, in that they produce the same sequence of strategies under the same sequence of utilities?

- ☐ A) Mirror descent and FTRL with entropic regularization
- ☐ B) Mirror descent and FTRL with Euclidean regularization
- ☒ C) Best-response dynamics and mirror descent with learning rate  $\eta = \infty$
- ☒ D) Fictitious play and FTRL with learning rate  $\eta = \infty$

22. Which of the following statements are true regarding computational game theory in Texas hold'em poker?

- ☒ A) The state-of-the-art abstractions are imperfect-recall games
- ☐ B) Libratus used a different strategy against different human opponents
- ☐ C) Reaching superhuman level in 6-player poker required more computation than reaching superhuman level in 2-player poker
- ☐ D) Libratus learned weaknesses in the humans' play and changed its strategy to exploit those weaknesses

23. Which of the following statements are true?

- ☐ A) Optimal play has been reached in 2-player no-limit Texas hold'em poker
- ☒ B) Superhuman play has been reached in Fog-of-War chess
- ☐ C) No strategy is known for beating AlphaGo
- ☒ D) Bluffing is helpful in Stratego

*perfect recall*

24. Consider a finite 2-player 0-sum extensive-form game. Which of the following statements are true?

- ☒ A) All Nash equilibrium strategies are minmax strategies
- ☒ B) By playing a non-equilibrium strategy, a player can in some cases cause the opponent's beliefs to be incorrect
- ☐ C) By playing a non-equilibrium strategy, a player can in some cases achieve higher expected utility against an opponent who plays one of the opponent's equilibrium strategies
- ☐ D) There is exactly one equilibrium

25. Which of the following statements are true?

- ☒ A) Every finite normal-form game has at least one equilibrium
- ☐ B) Finite 2-player 0-sum extensive-form games can be solved in polynomial time
- ☒ C) In (finite) normal-form 2-player games, finding a Nash equilibrium is PPAD-complete.
- ☐ D) In (finite) normal-form 2-player 0-sum games, a player's set of minmax strategies can be disconnected

*ME Nash*

*Exact*