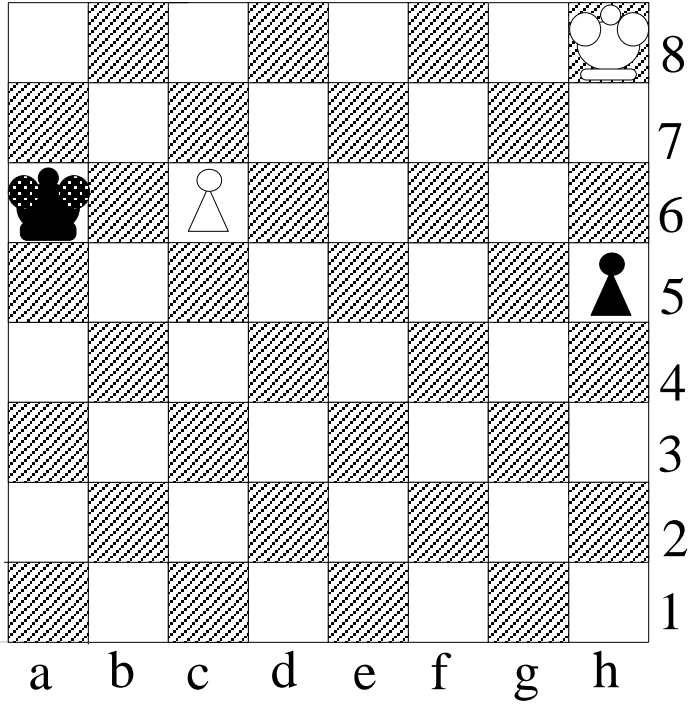


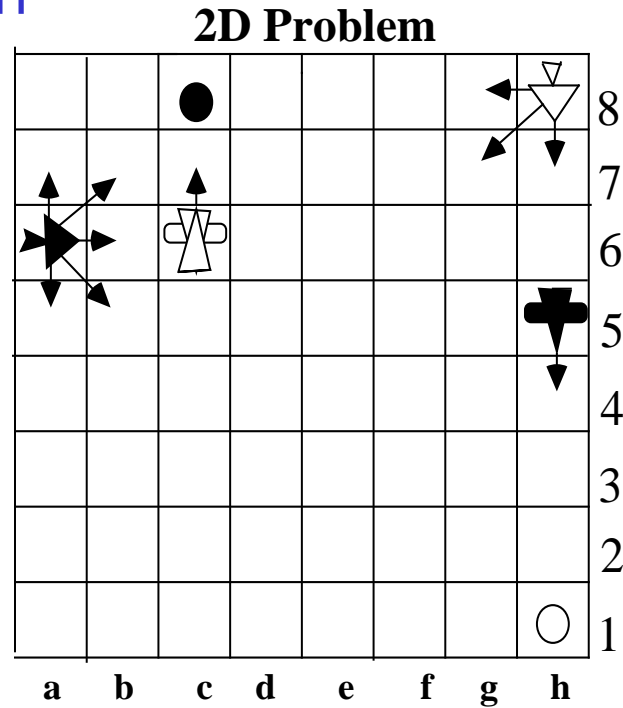
Linguistic Geometry Tools: Solving Intractable Search Problems without Search

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University of Colorado Denver, USA
STILMAN Advanced Strategies, USA

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□ Sample Problem



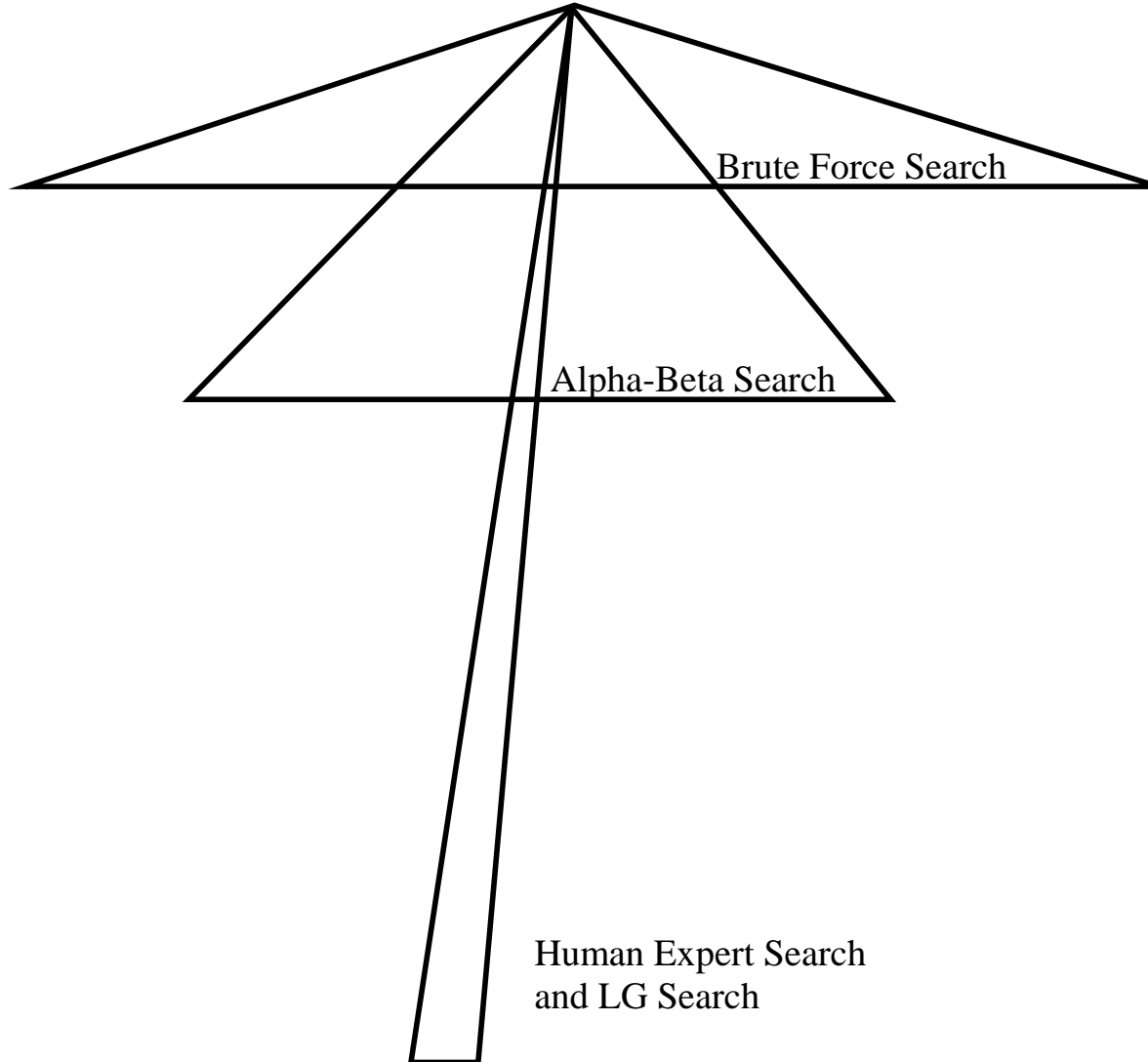
Is there a strategy for the White to make a draw?

The specific question is as follows.

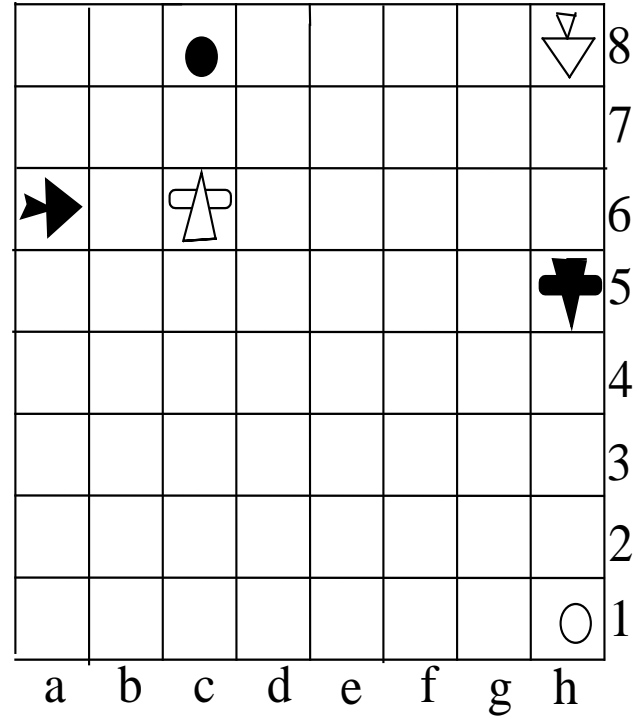
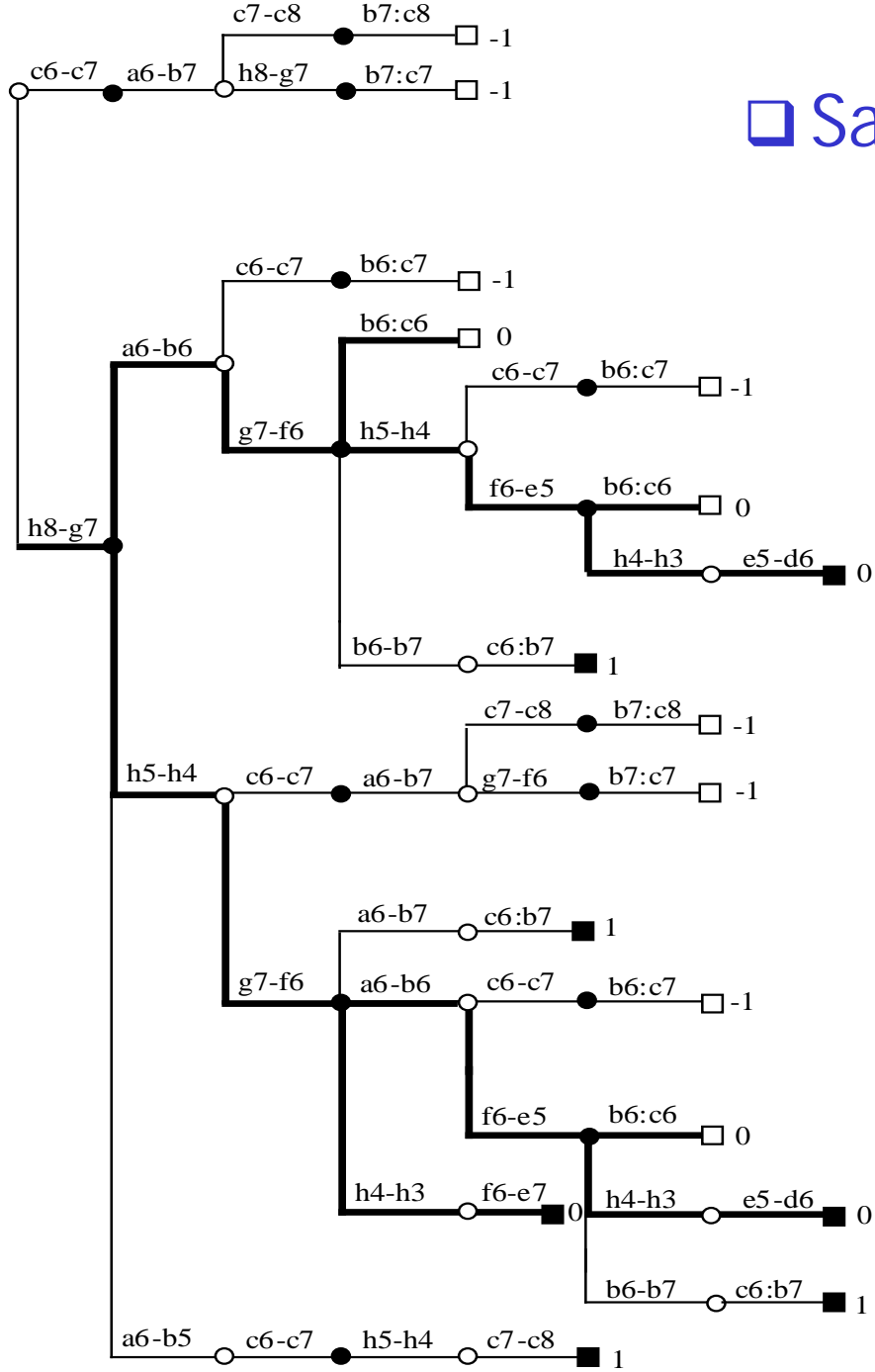
Is there an optimal strategy that provides one of the following?

1. Both BOMBERS hit their targets on subsequent time increments and stay safe for at least one time increment.
2. Both BOMBERS are destroyed before they hit their targets or immediately after that.

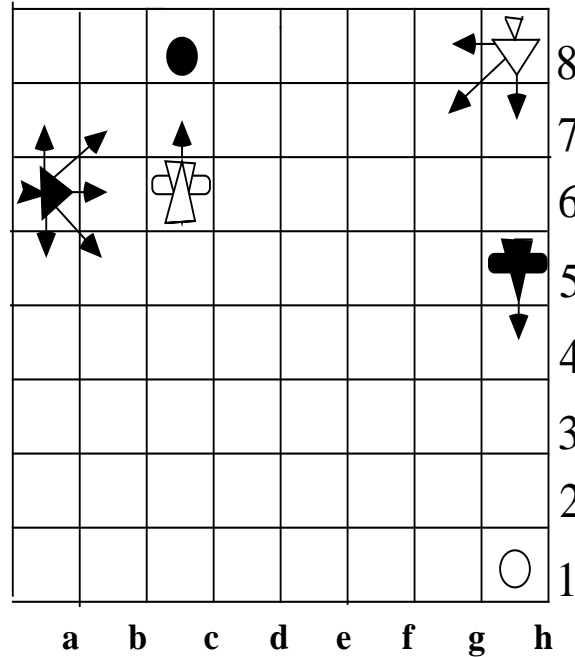
Different Searches (for the same processing time)



Sample Problem: LG Search



2D Problem: Terminal Sets

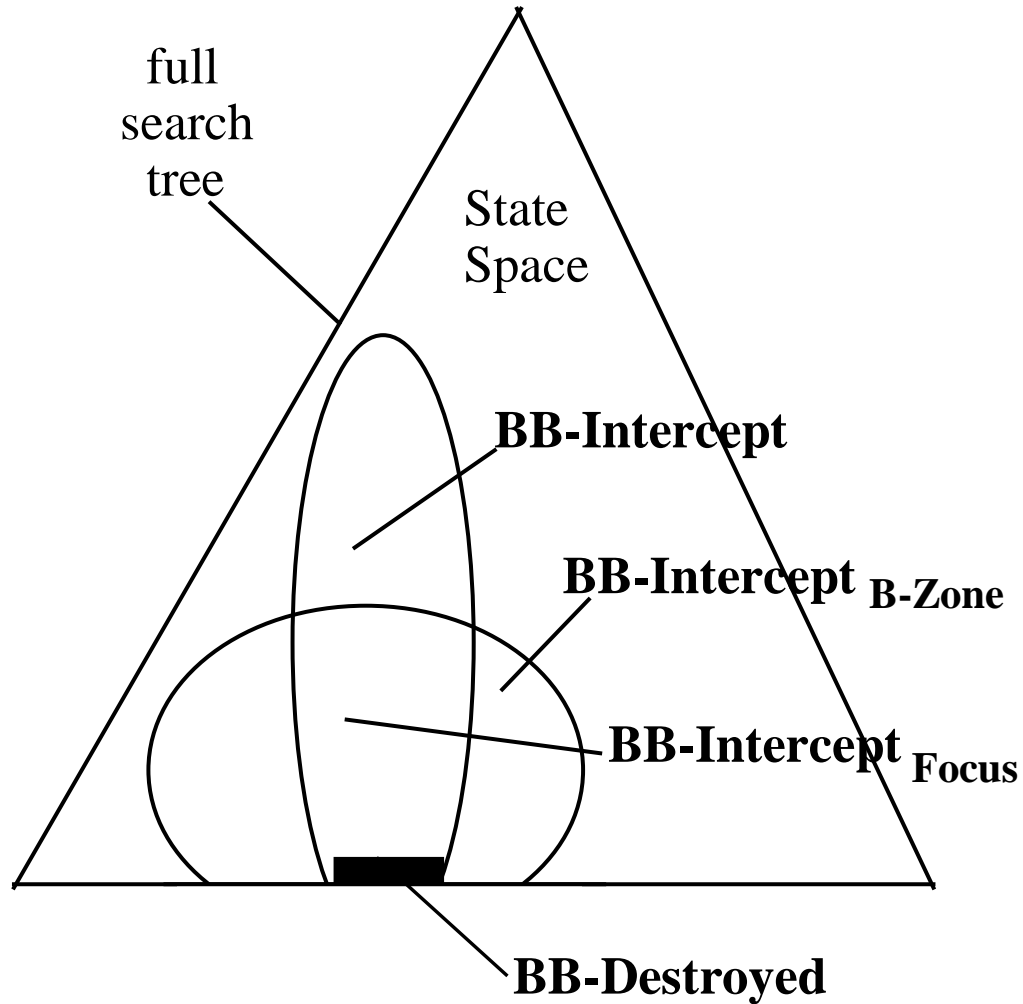


1. **W-Win** = **BB-Destroyed** \cap **WB-Safe**
2. **B-Win** = **WB-Destroyed** \cap **BB-Safe**
3. **Draw** = **Safe** \cup **Destroyed**, where
Destroyed = **BB-Destroyed** \cap **WB-Destroyed**,
Safe = **BB-Safe** \cap **WB-Safe**

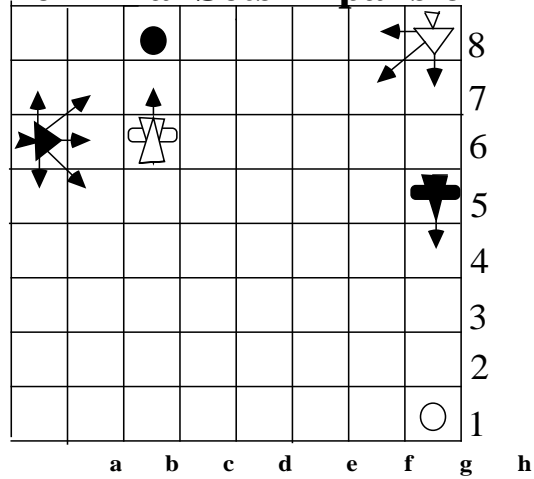
Let **A** be a set of states.

The strategy is called an **A strategy** if it is represented by the optimal subtree with the terminal nodes which represent states from **A**, only.

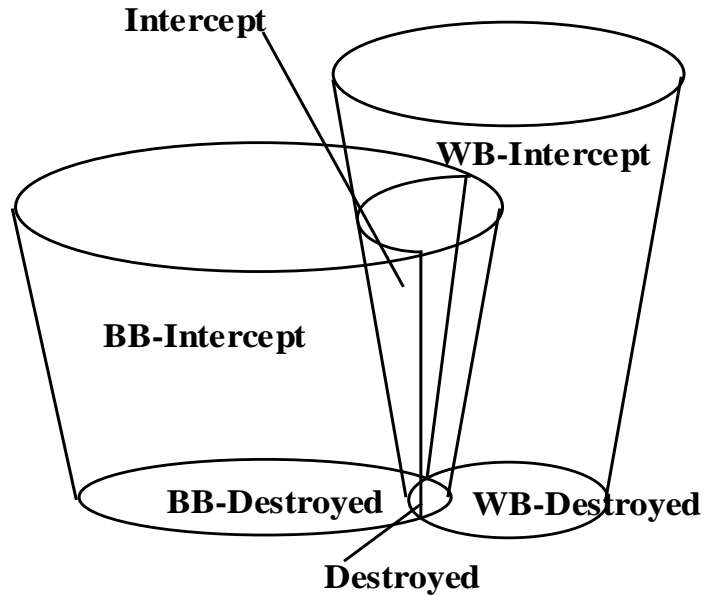
Why do we need the terminal sets expansion?



Terminal Sets Expansion



BB-Intercept is the set of states
where **BB-Destroyed** strategy exists

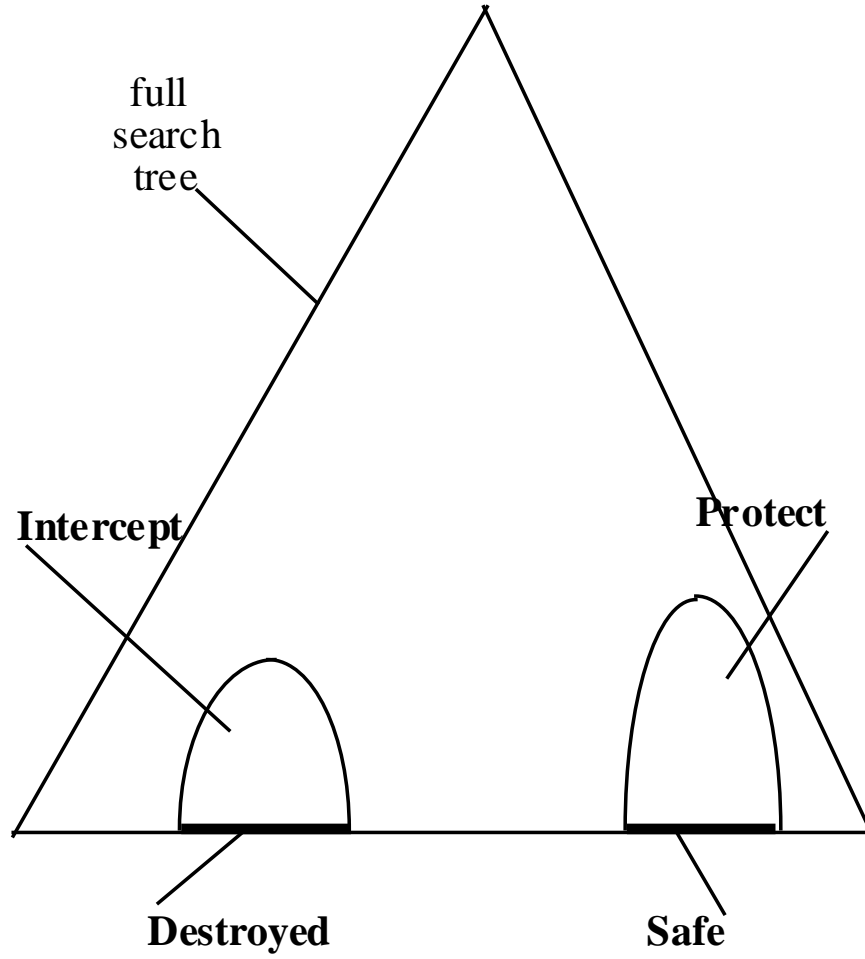


$$\text{Intercept} = \text{BB-Intercept} \cap \text{WB-Intercept}$$

$$\text{Destroyed} = \text{BB-Destroyed} \cap \text{WB-Destroyed}.$$

$$\text{Destroyed} \subset \text{DrawExpand}.$$

Expanded Terminal States



Terminal Sets Expansion

$$\mathbf{Intercept} = \mathbf{BB-Intercept} \cap \mathbf{WB-Intercept}$$

is the set of states where the **Destroyed strategy** exists

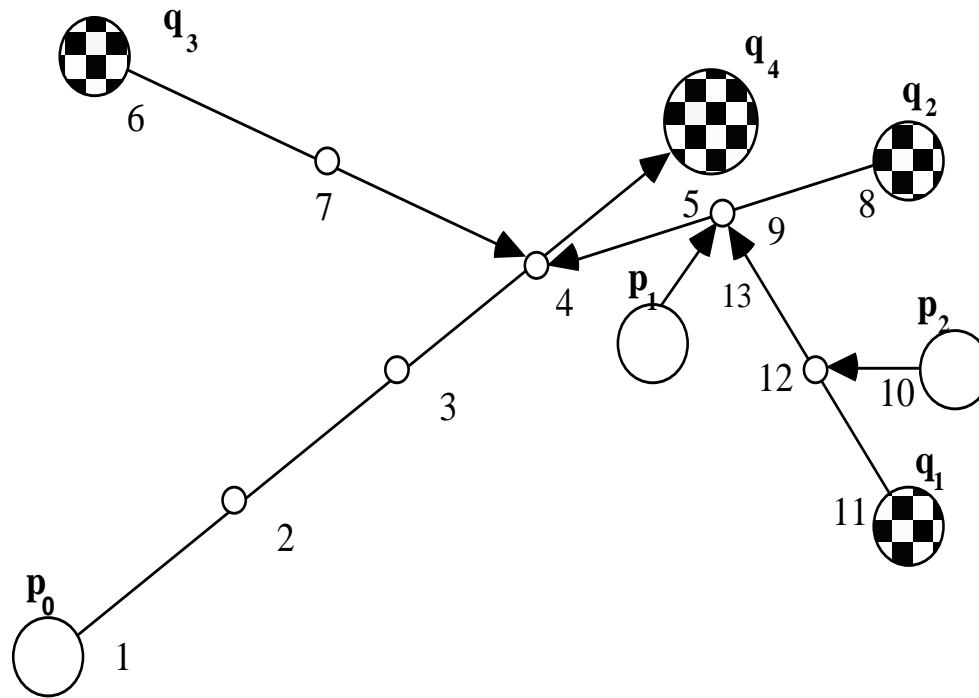
$$\mathbf{Destroyed} = \mathbf{BB-Destroyed} \cap \mathbf{WB-Destroyed}.$$

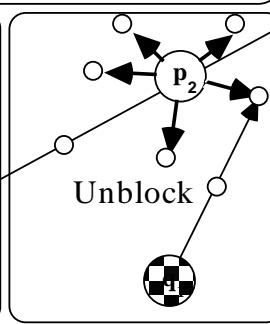
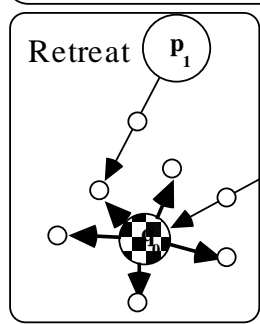
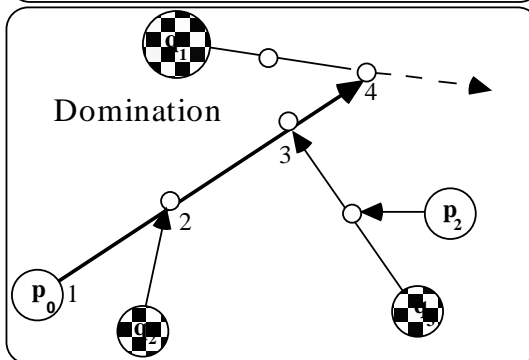
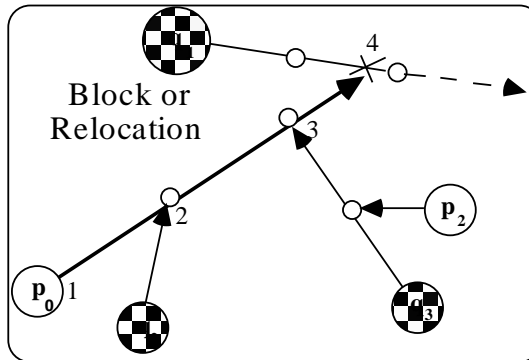
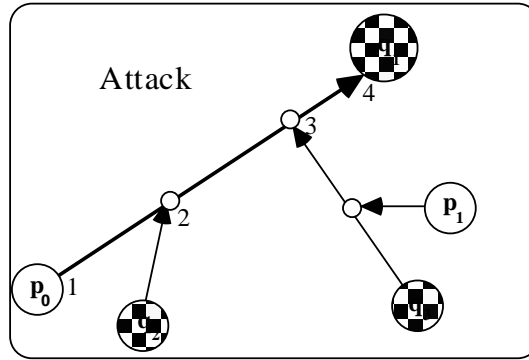
$$\mathbf{Protect} = \mathbf{BB-Protect} \cap \mathbf{WB-Protect}$$

is the set of states where the **Safe strategy** exists

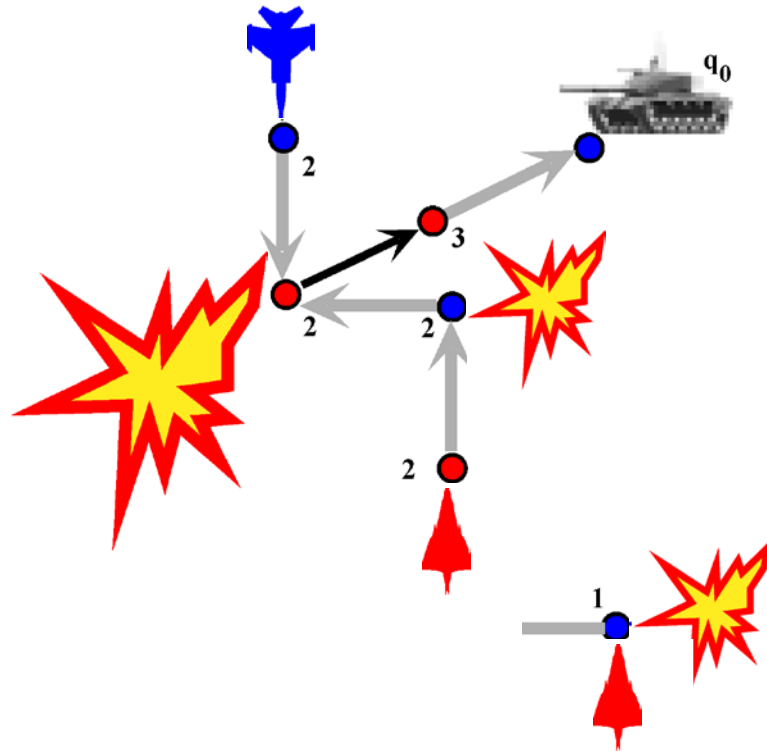
$$\mathbf{Safe} = \mathbf{BB-Safe} \cap \mathbf{WB-Safe}.$$

LG Zone

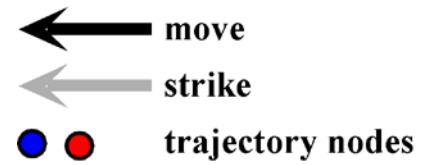




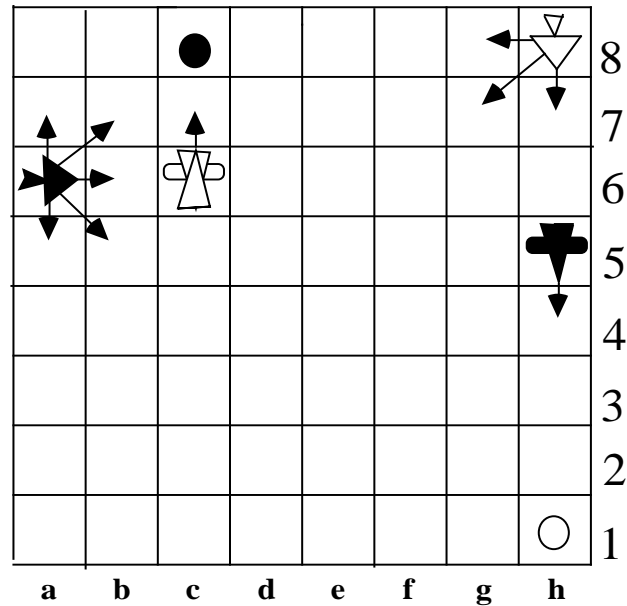
Types of Zones



Concurrent Zones for Defense Systems

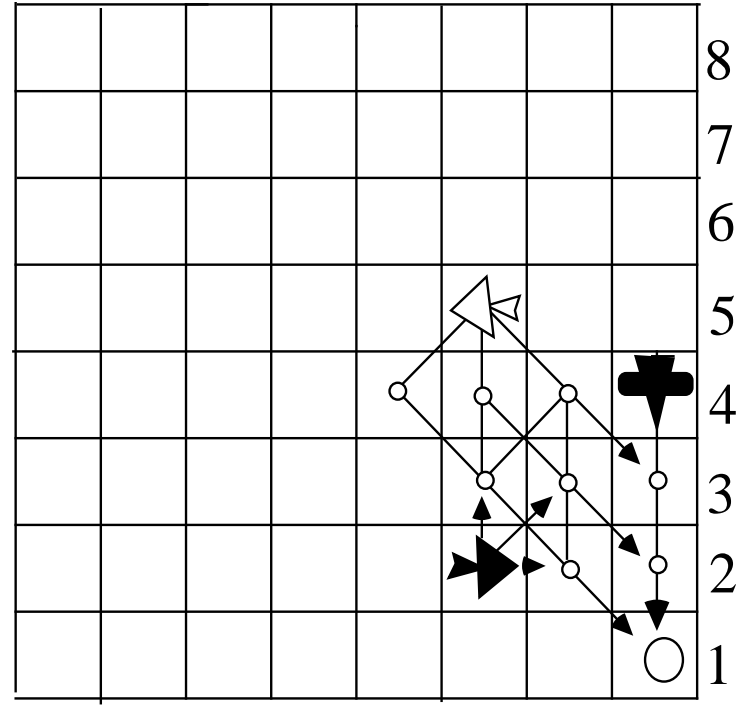
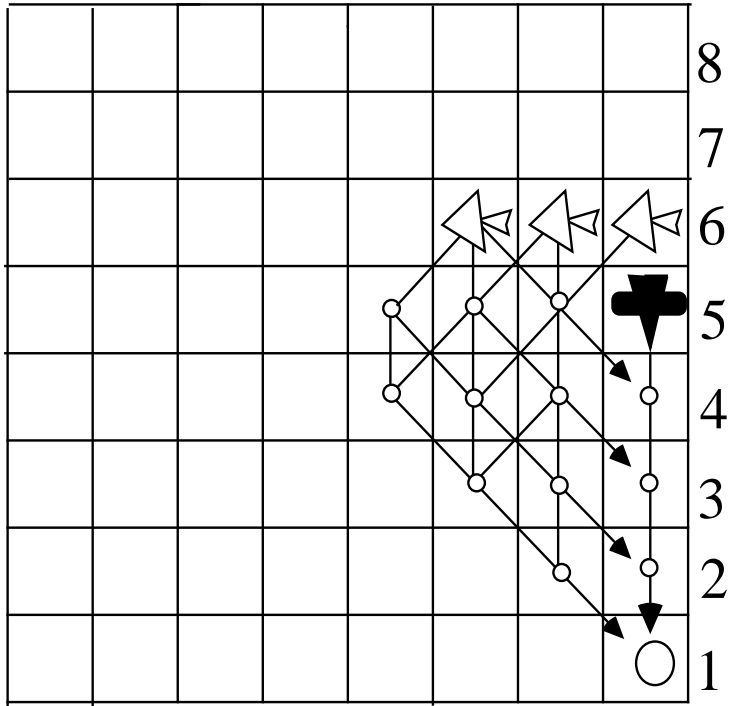


Structure of Expanded Terminal Sets

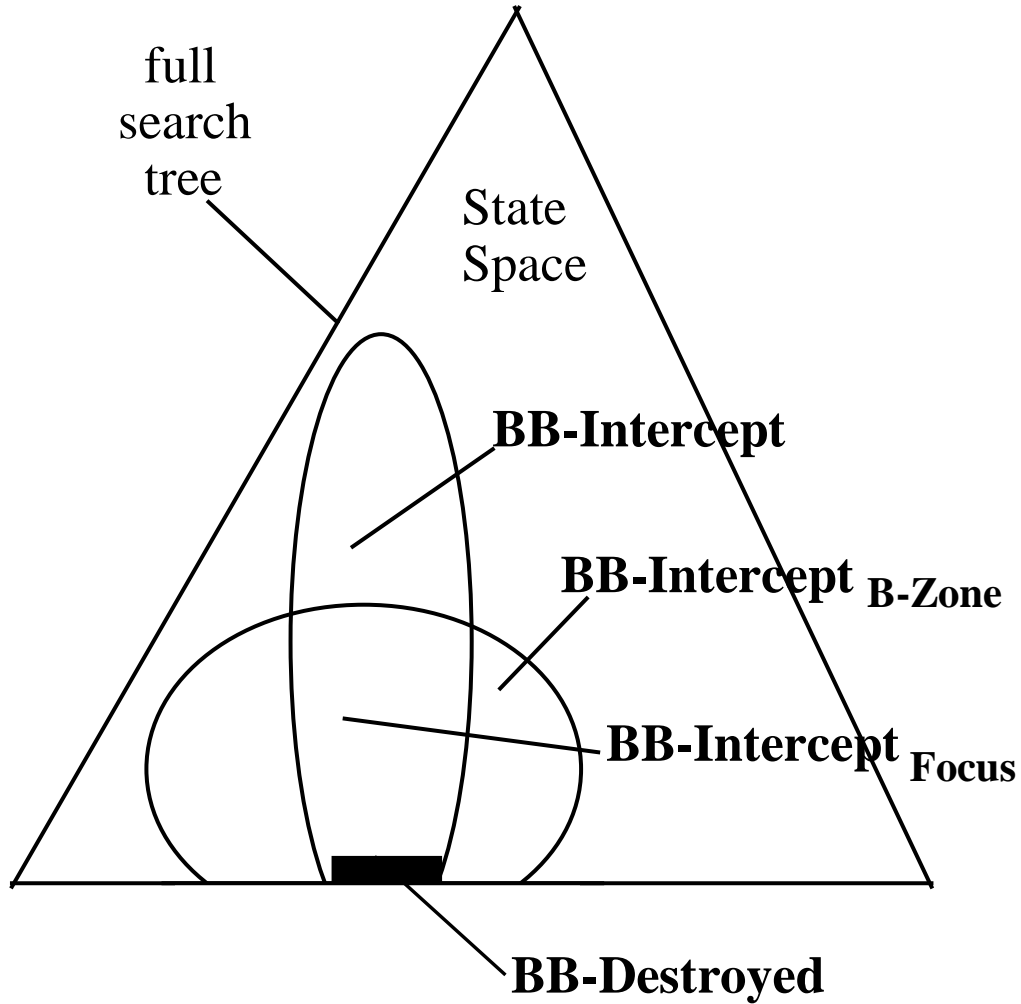


Structure of BB-Intercept,
the set of states
where **BB-Destroyed strategy** exists

Structure of Expanded Terminal Sets: BB-Intercept _{B-Zone}

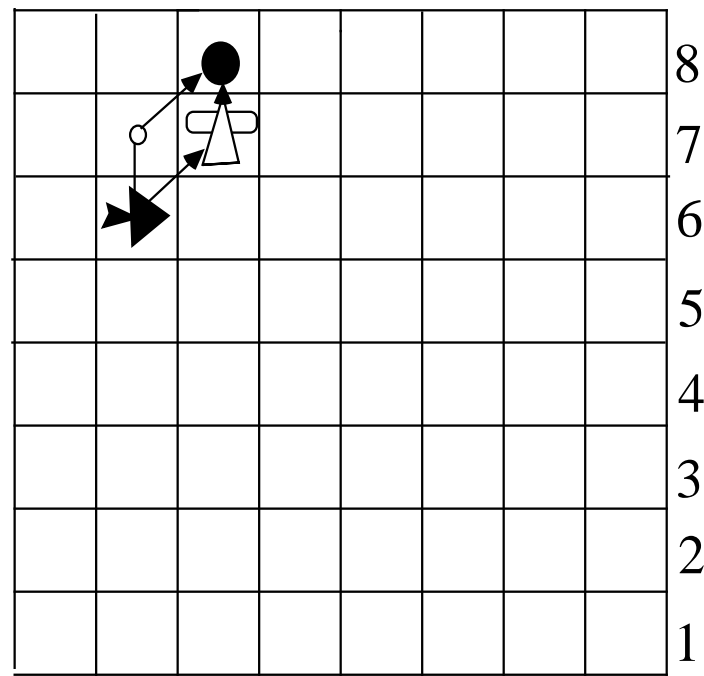
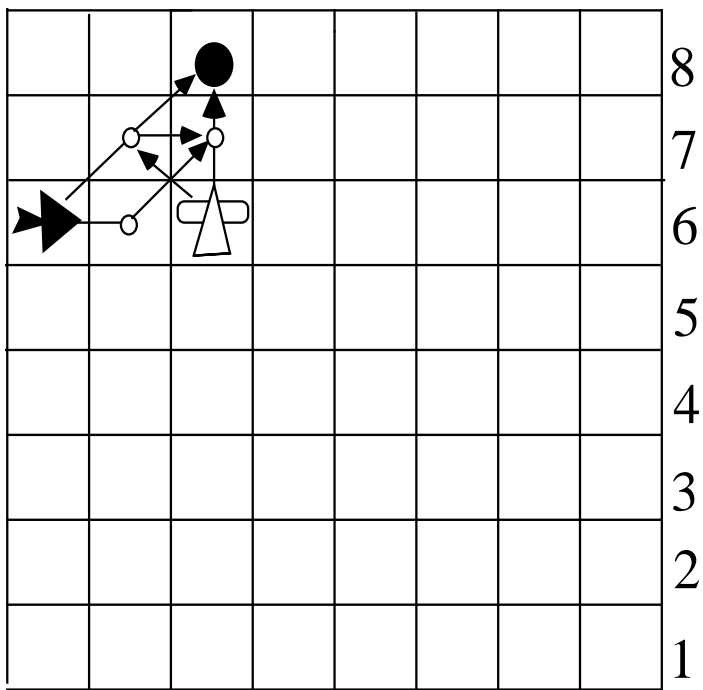


What has been achieved?



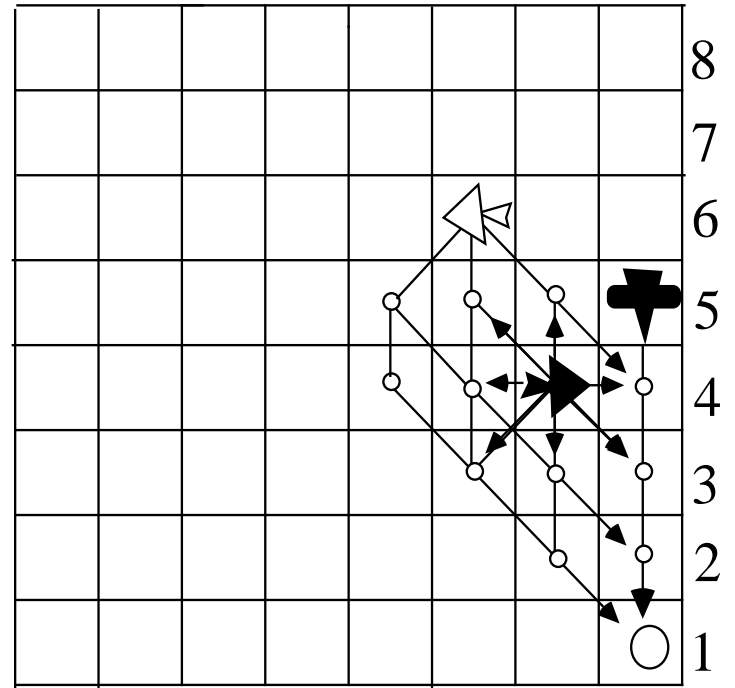
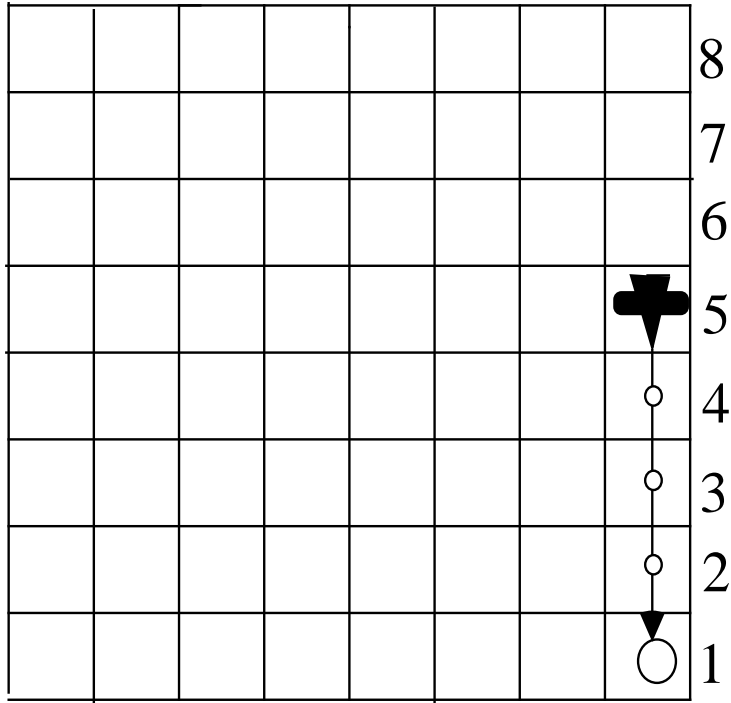
Structure of Expanded Terminal Sets

WB-Intercept_{W-Zone}



Structure of Expanded Terminal Sets

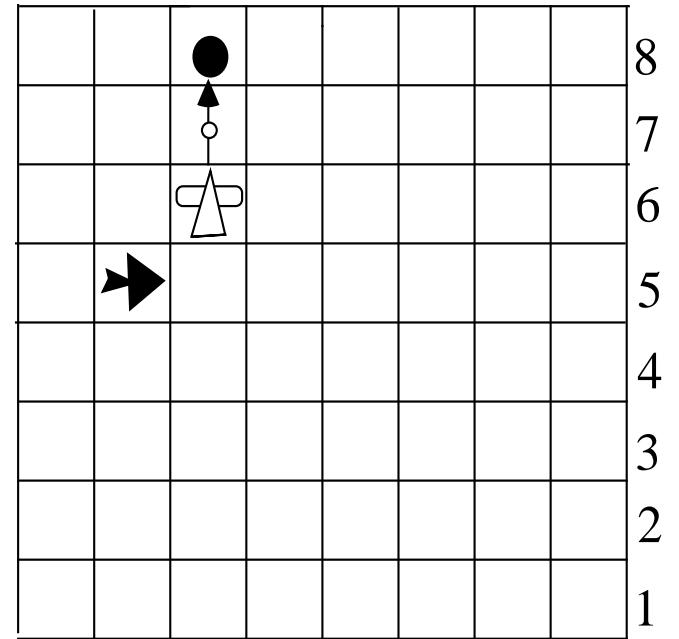
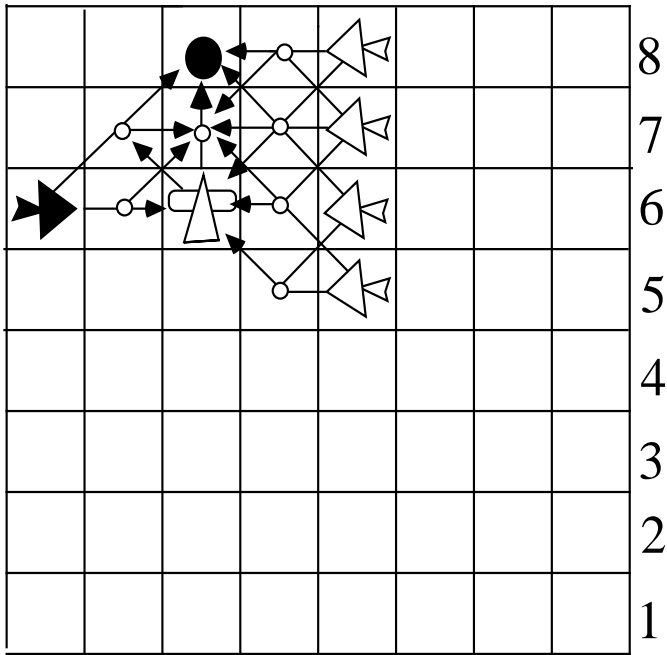
BB-Protect_{B-Zone}



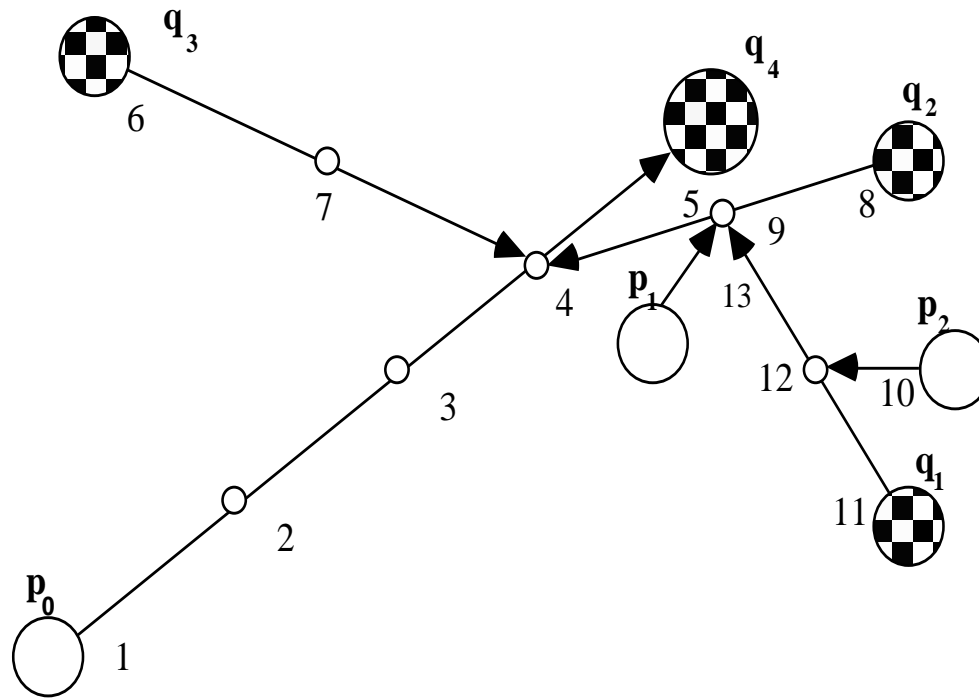
Structure of Expanded Terminal Sets

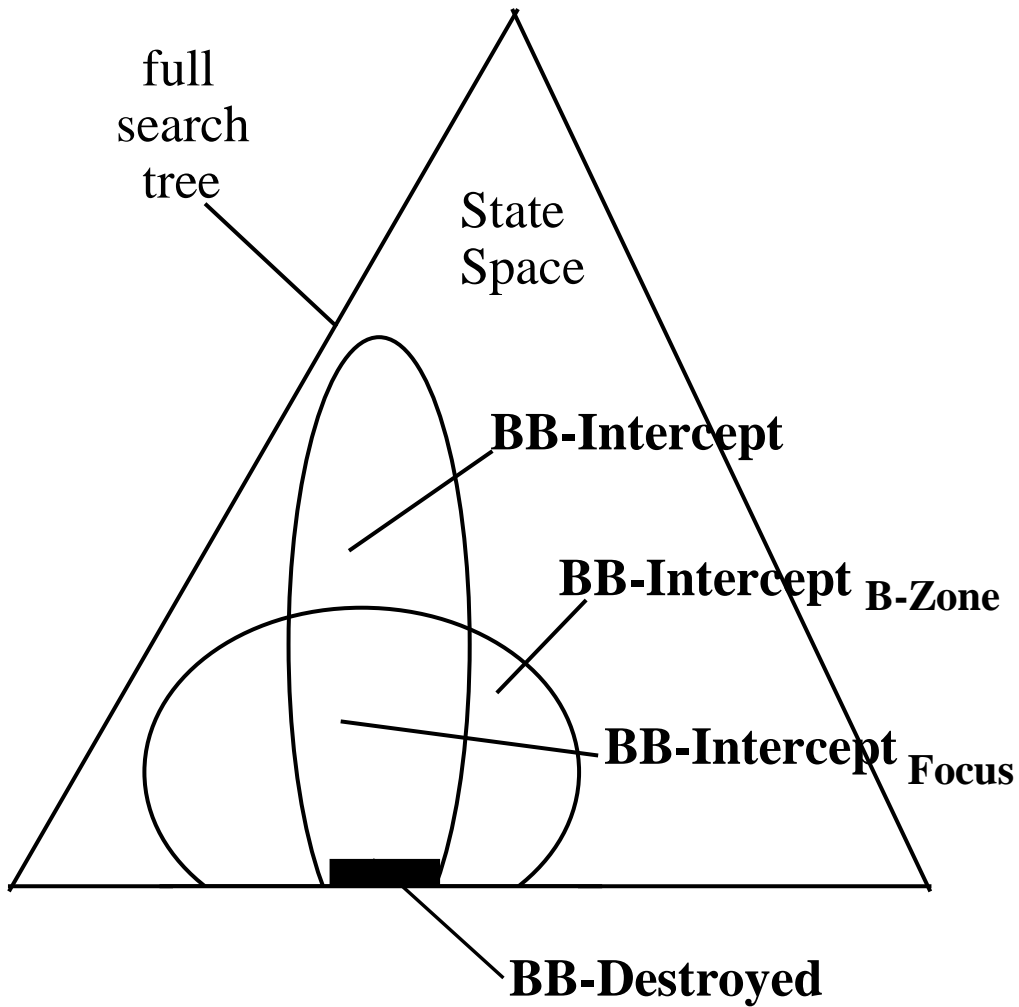
WB-Protect

W-Zone



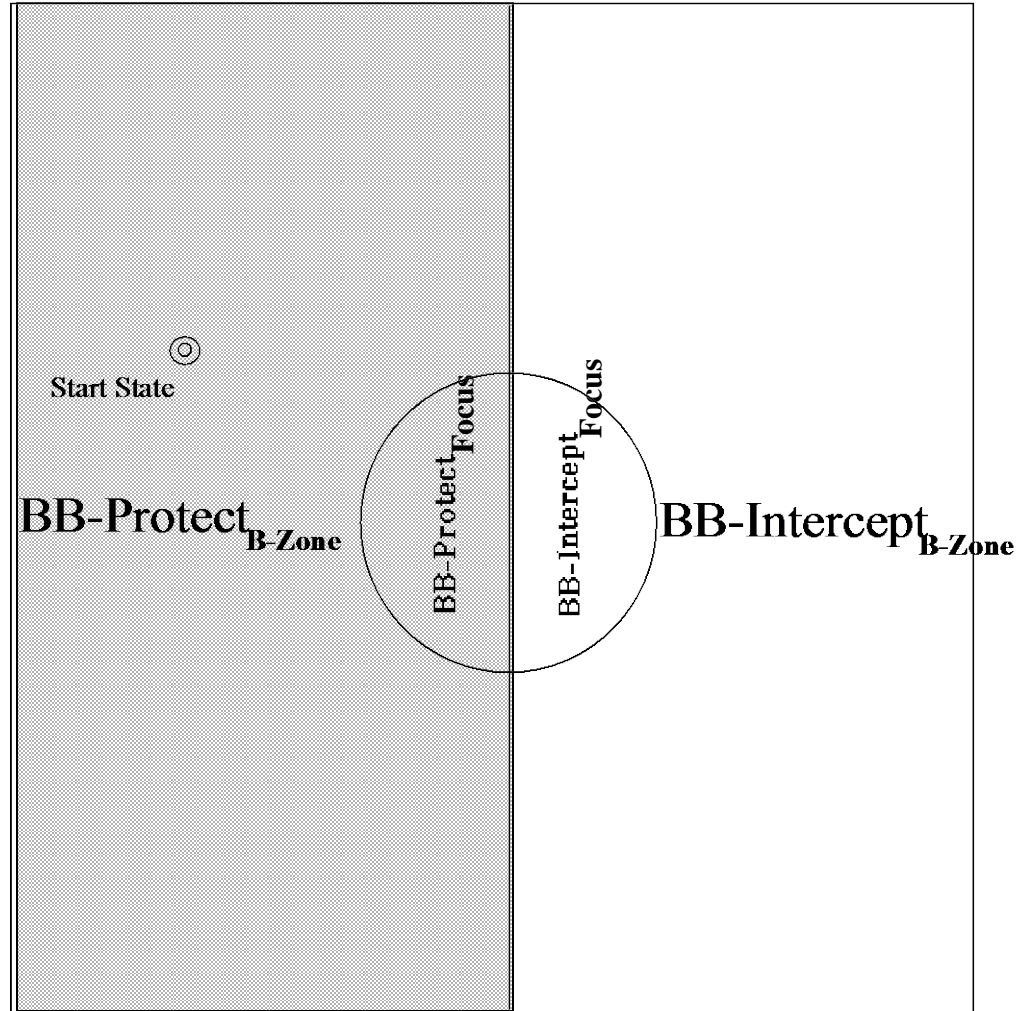
LG Zone





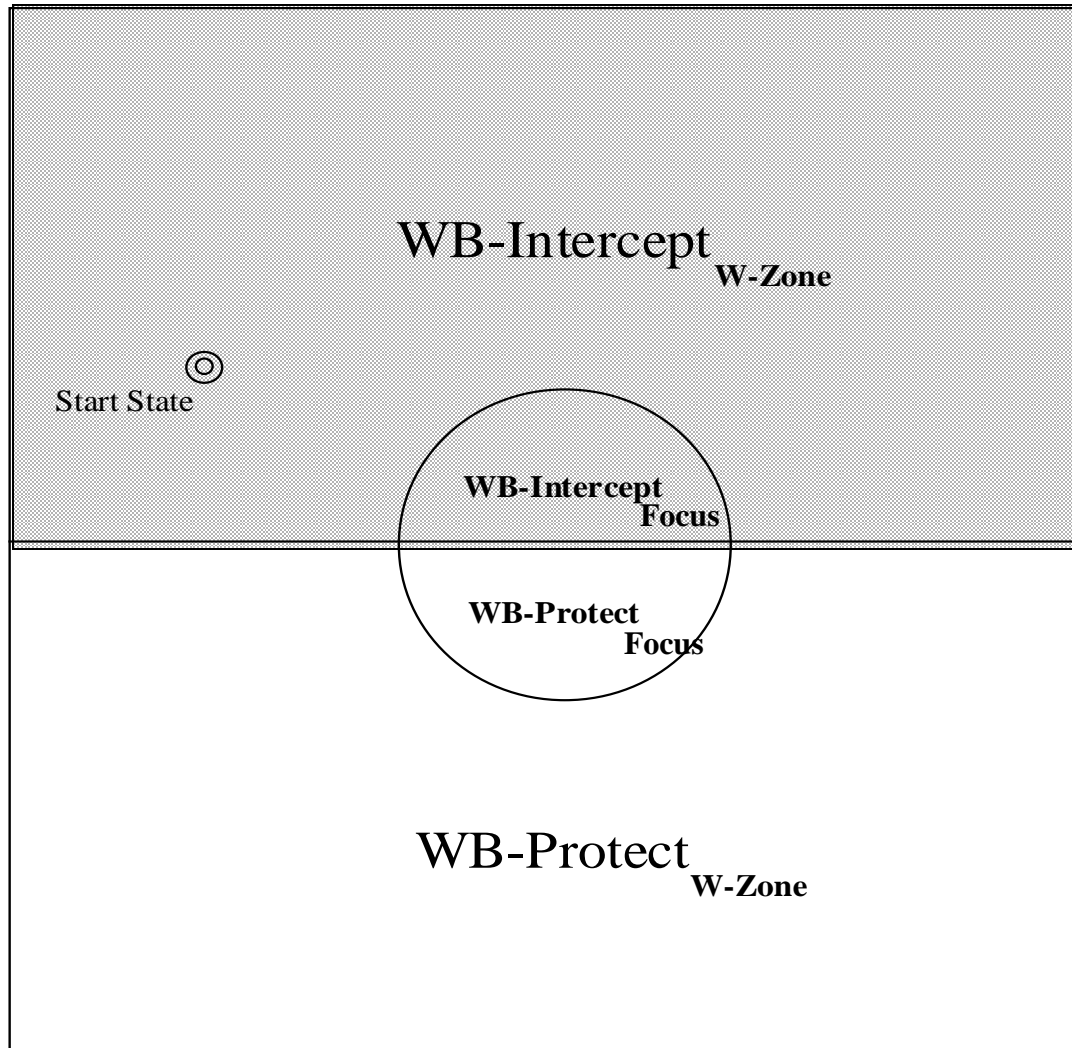
State Space Decomposition

$$\text{SPACE} = \text{BB-Protect}_{\text{B-Zone}} \cup \text{BB-Intercept}_{\text{B-Zone}}$$

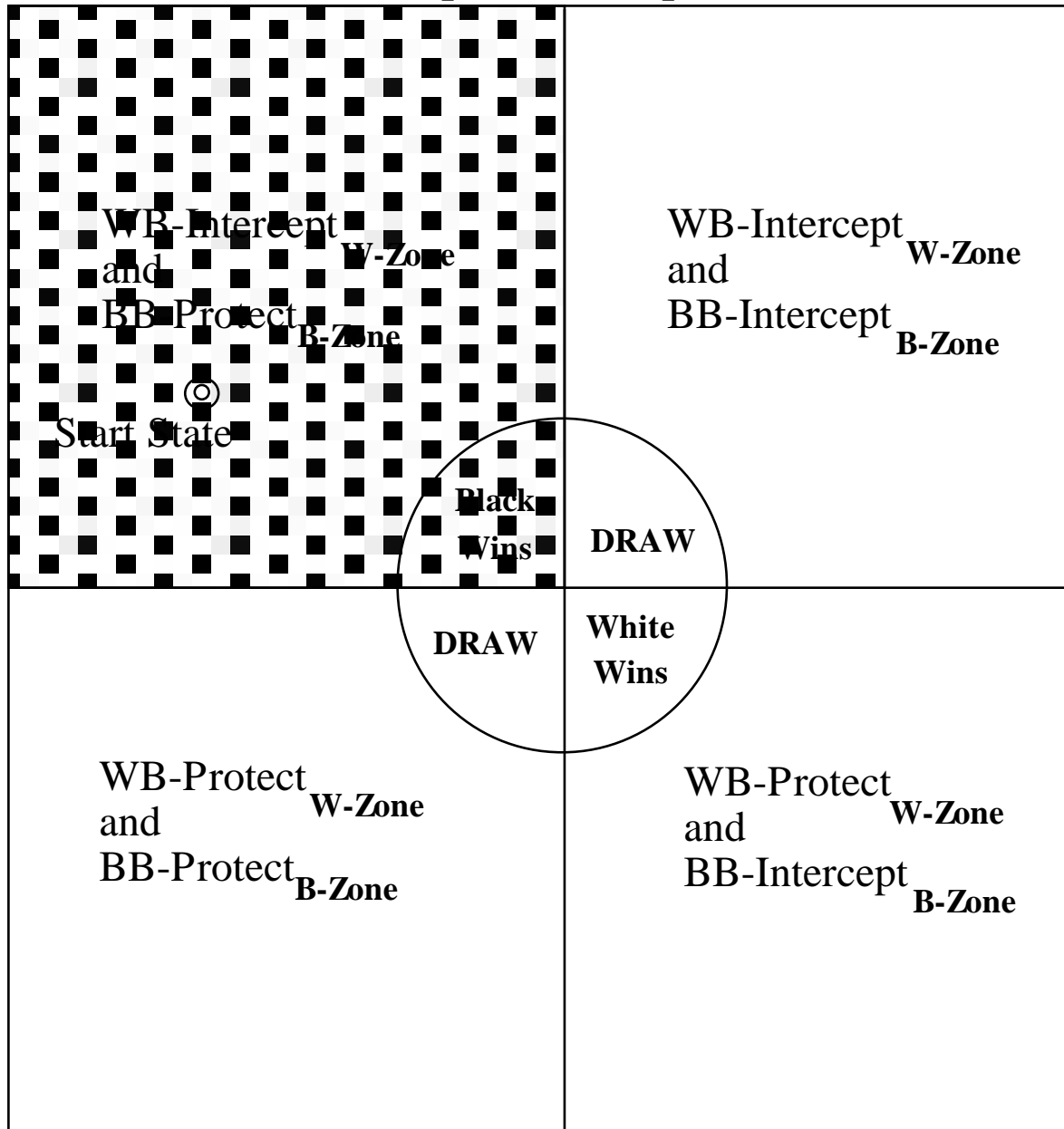


State Space Decomposition

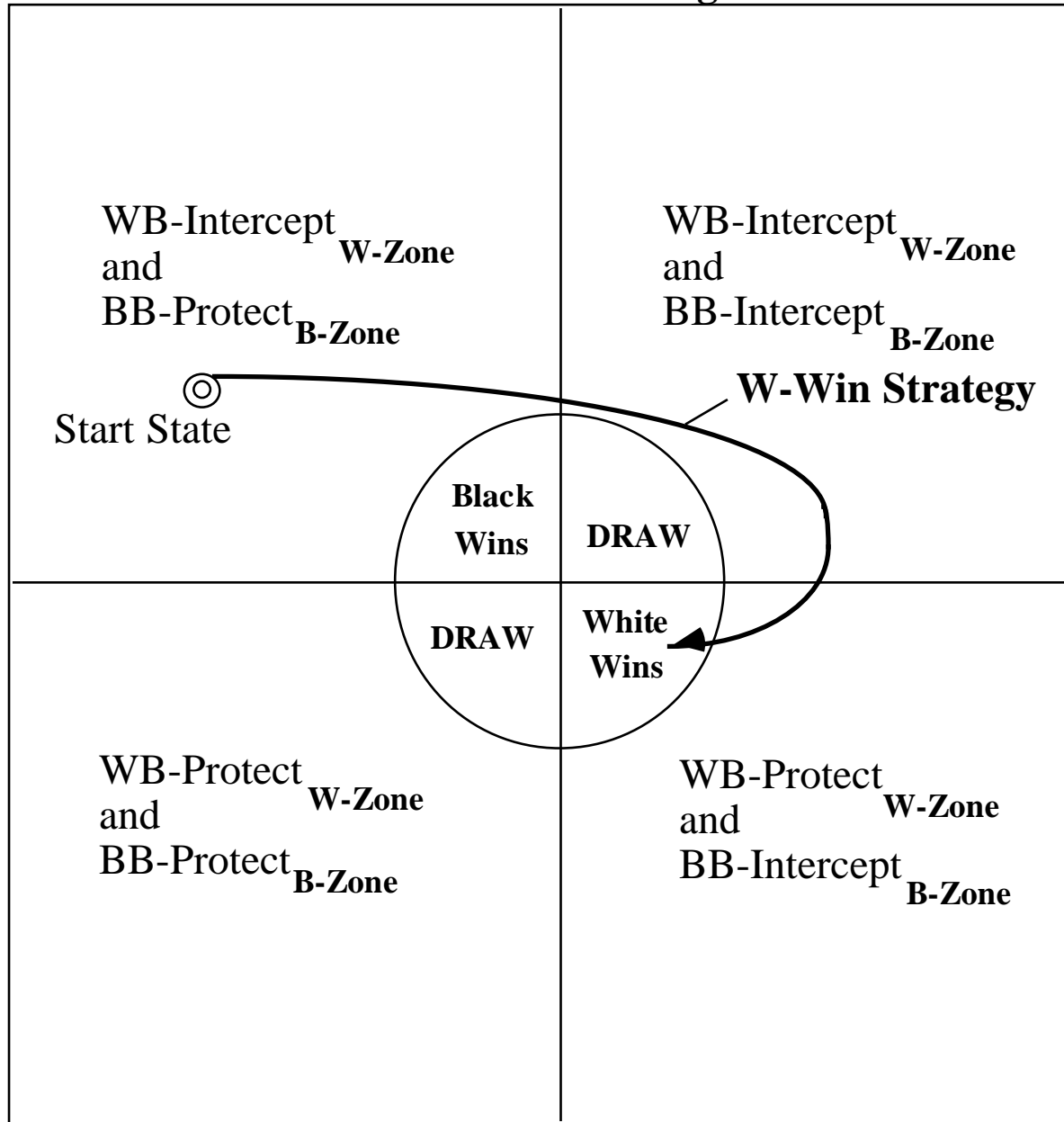
$$\text{SPACE} = \text{WB-Protect}_{\text{W-Zone}} \cup \text{WB-Intercept}_{\text{W-Zone}}$$



State Space Decomposition



Intend-to-Win Strategies



Intend-to-Win Strategies

In reality, *only one of them takes place.*

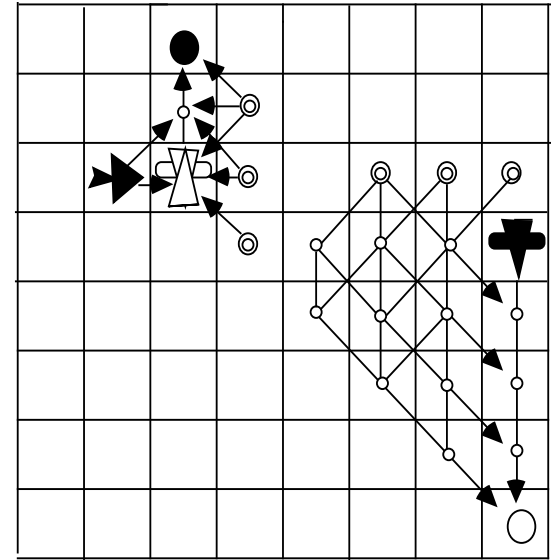
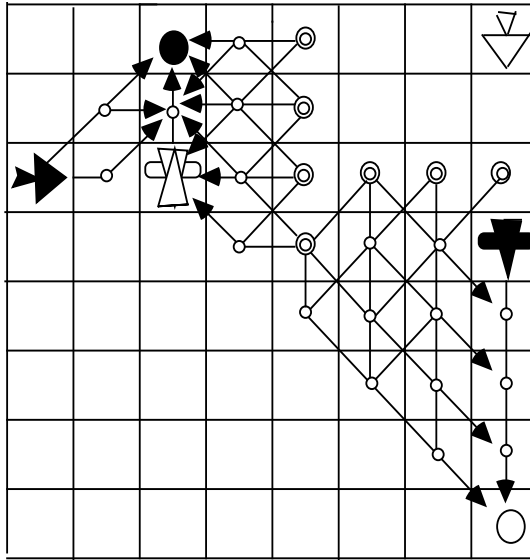
1. W-Win strategy: $W\text{-Win} = WB\text{-Safe} \cap BB\text{-Destroyed}$

The W-Win strategy, if it exists, is to change the status of both
W-Zone and B-Zone,

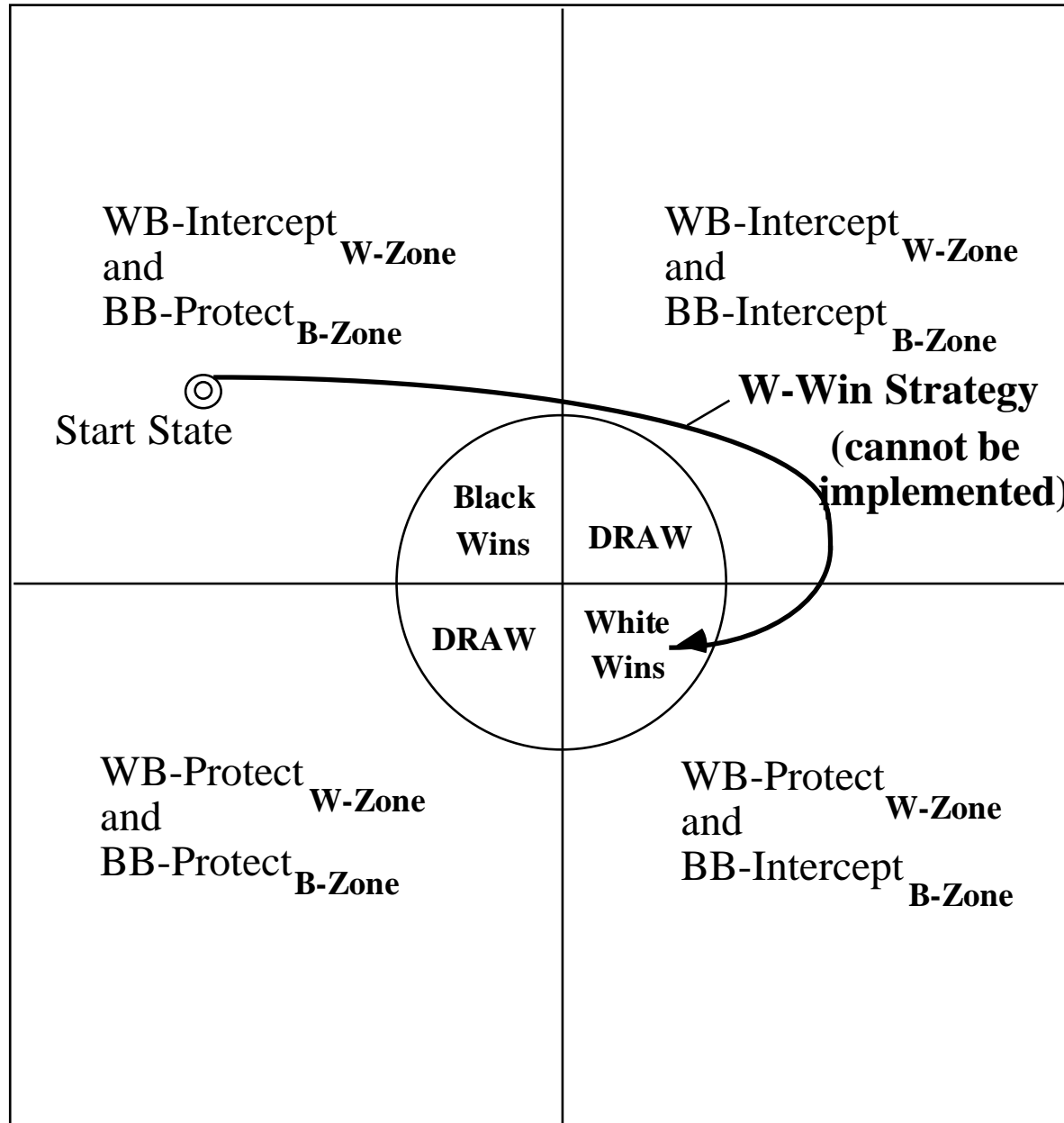
$$WB\text{-Intercept}_{W\text{-Zone}} \cap BB\text{-Protect}_{B\text{-Zone}}$$



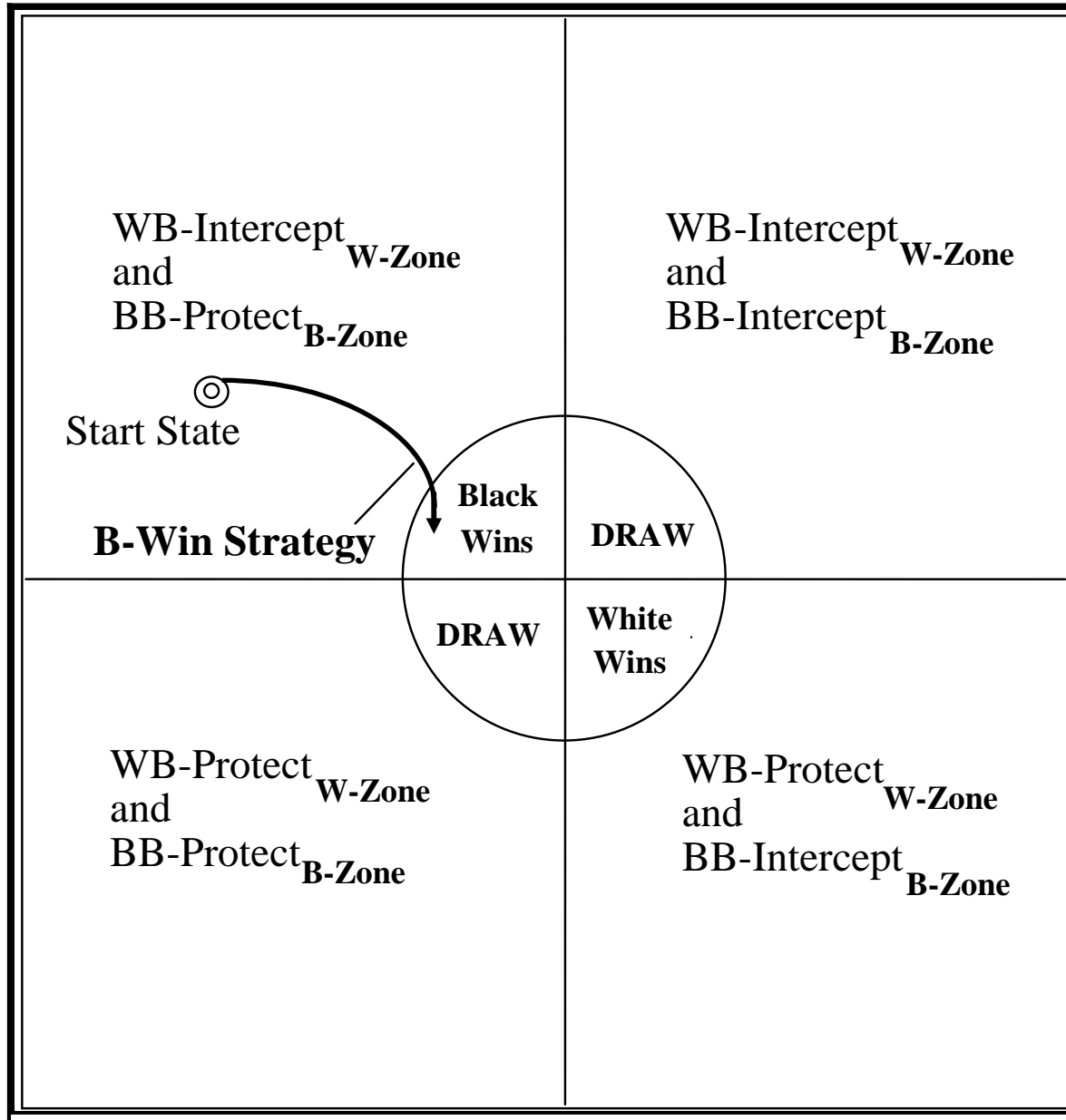
$$WB\text{-Protect}_{\text{Focus}} \cap BB\text{-Intercept}_{\text{Focus}}$$



Intend-to-Win Strategies



Intend-to-Win Strategies



Intend-to-Win Strategies

In reality, *only one of them takes place.*

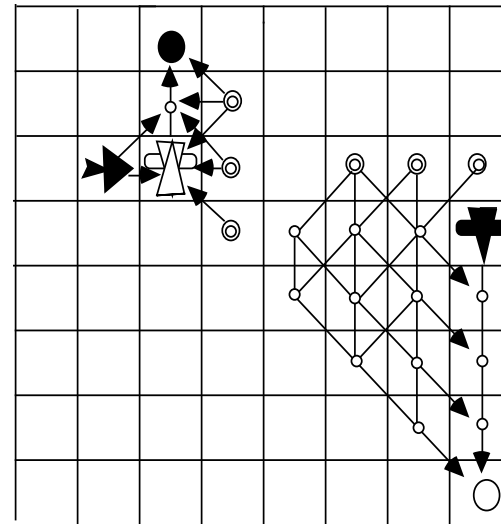
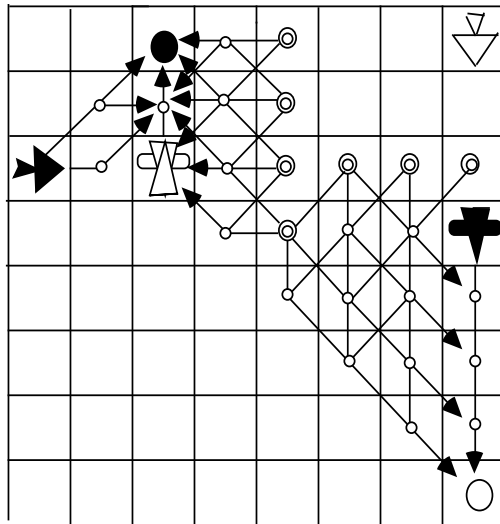
2. B-Win strategy: $B\text{-Win} = WB\text{-Destroyed} \cap BB\text{-Safe}$

The B-Win strategy, if it exists, is to keep the status of **both**
W-Zone and B-Zone
 unchanged as they are in the Start State.

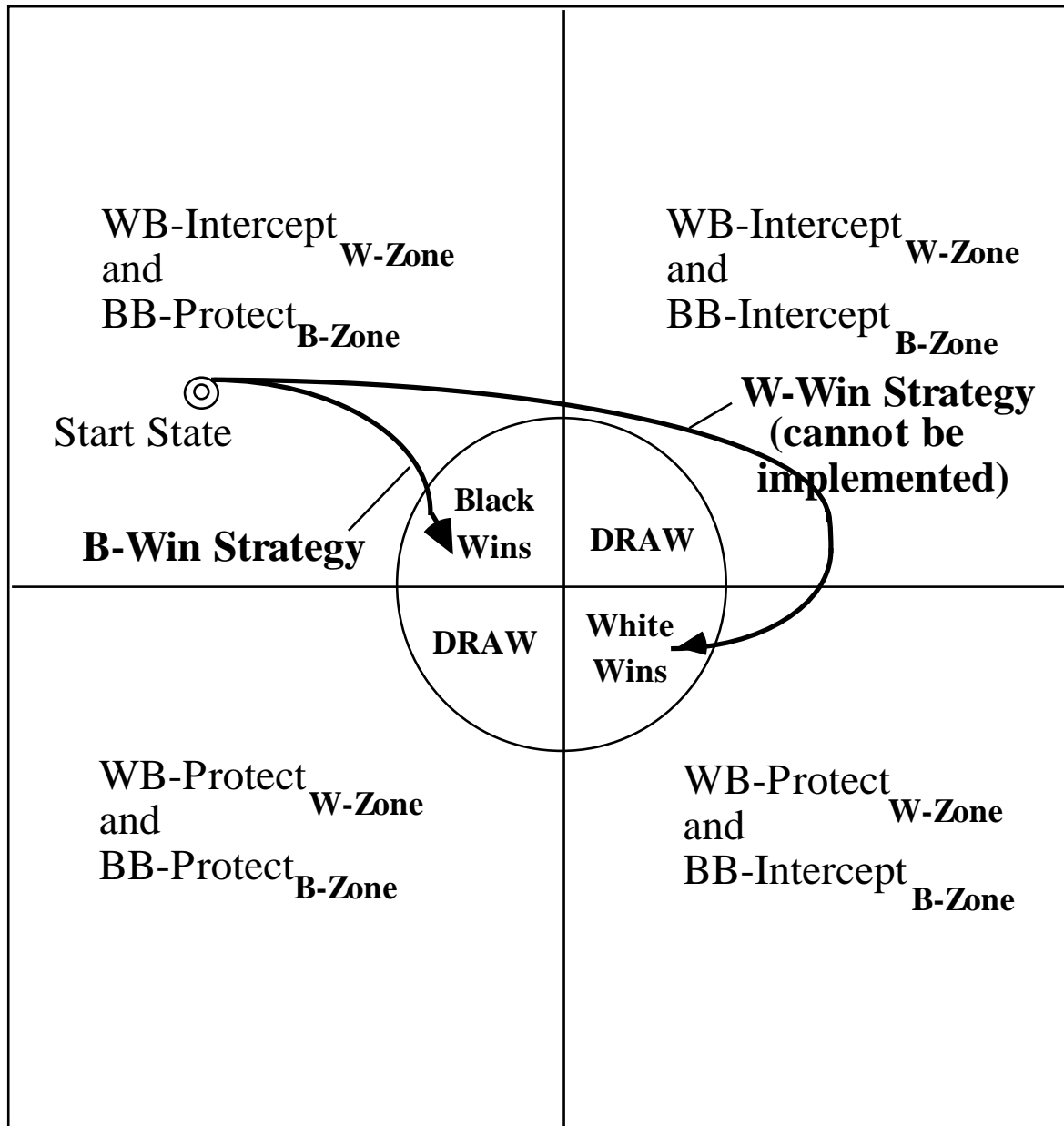
$$WB\text{-Intercept}_{W\text{-Zone}} \cap BB\text{-Protect}_{W\text{-Zone}}$$



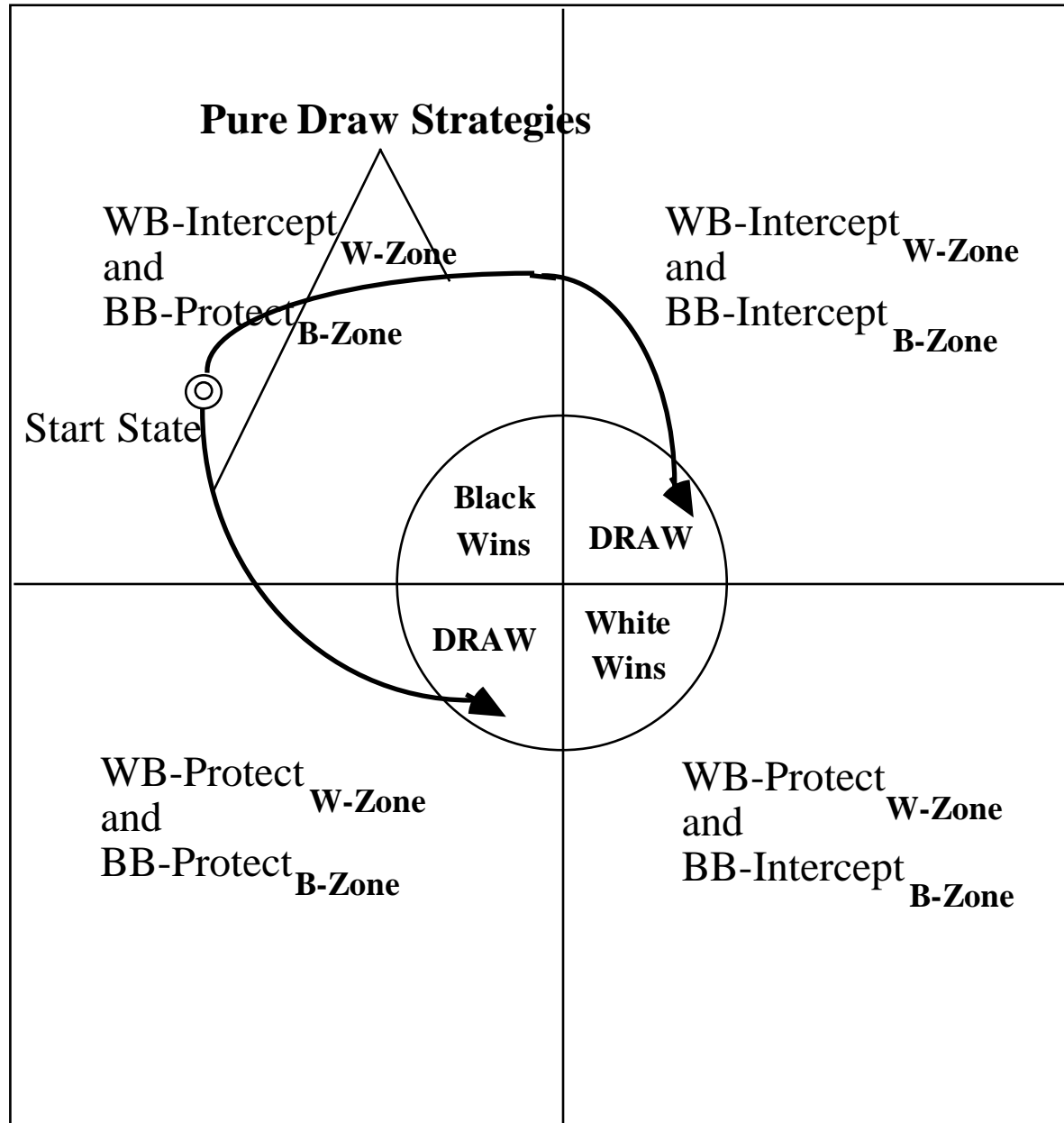
$$WB\text{-Intercept}_{\text{Focus}} \cap BB\text{-Protect}_{\text{Focus}}$$



Intend-to-Win Strategies



Intend-to-Draw Strategies



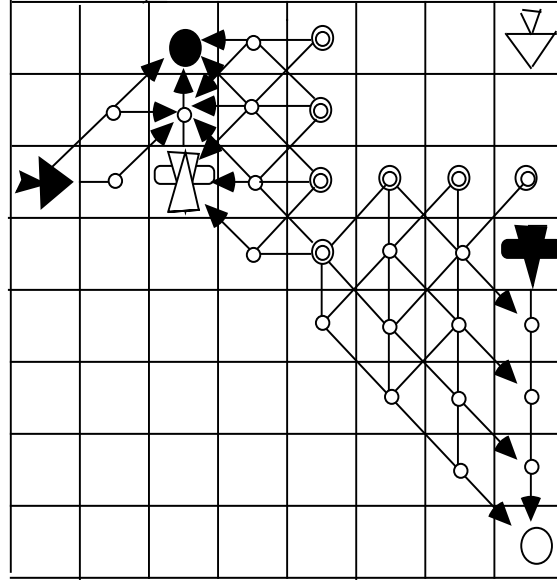
Pure Draw Strategy

$$\text{StateDist1} = \text{sd}(\text{Current State}, \text{WB-Protect}_{\text{W-Zone}})$$

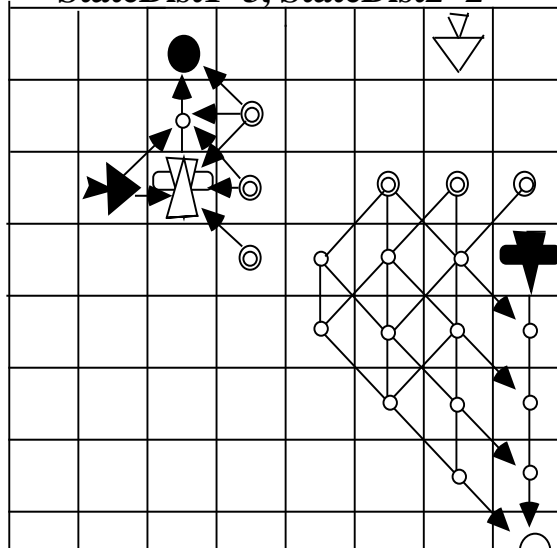
$$\text{StateDist2} = \text{sd}(\text{Current State}, \text{BB-Intercept}_{\text{B-Zone}})$$

$$\text{StateDist} = \text{StateDist1} + \text{StateDist2}$$

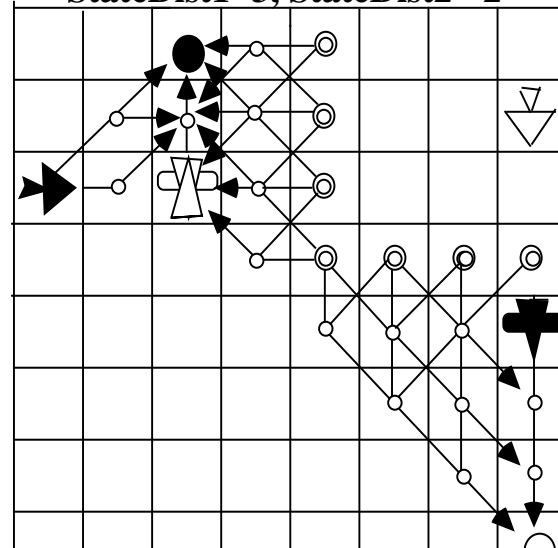
$$\text{StateDist1} = 3, \text{StateDist2} = 2 \Rightarrow \text{StateDist} = 5$$



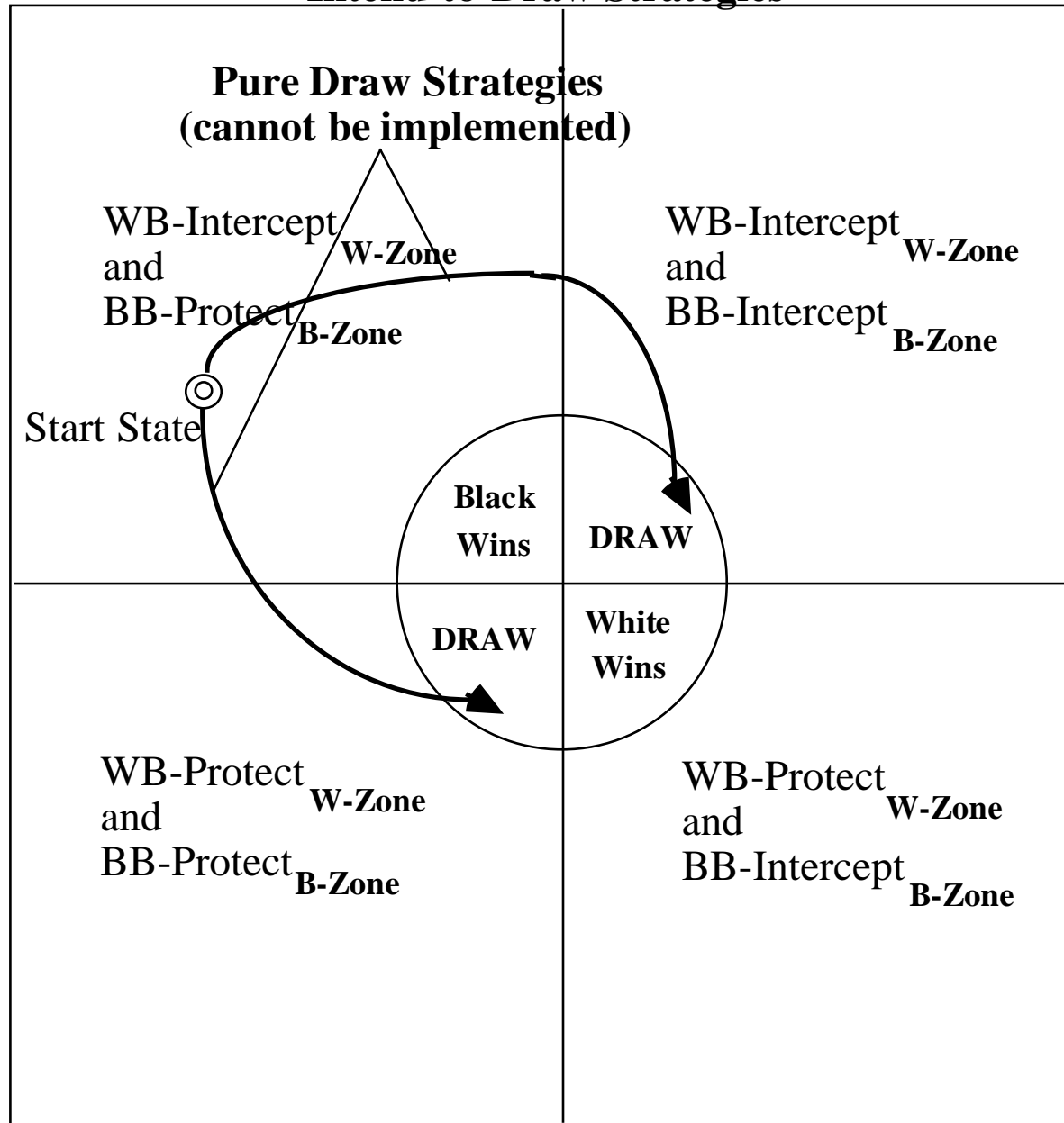
StateDist1=3, StateDist2=2



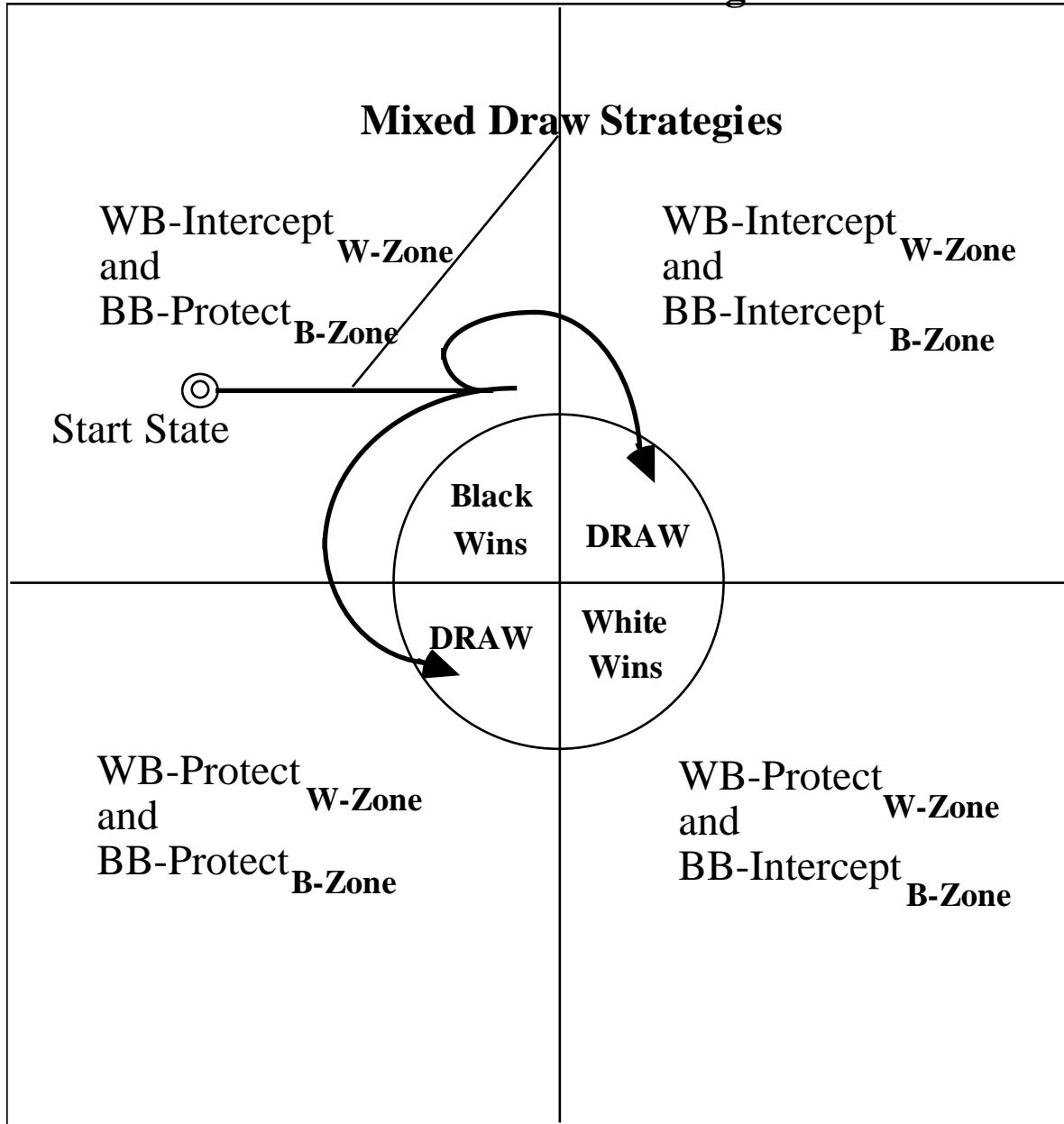
StateDist1=3, StateDist2=2



Intend-to-Draw Strategies



Intend-to-Draw Strategies



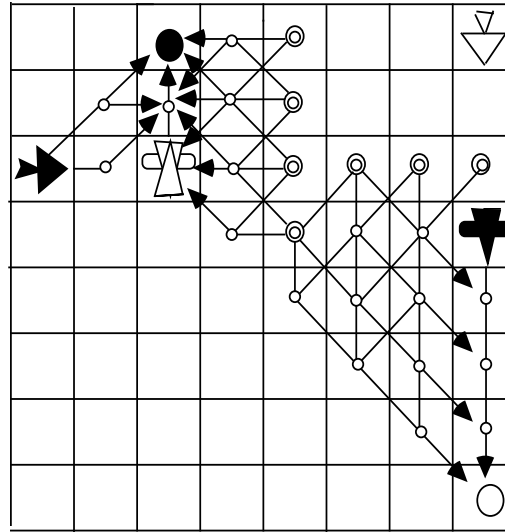
Mixed Draw Strategy

$$\text{StateDist1} = \text{sd}(\text{Current State}, \text{WB-Protect}_{\text{W-Zone}})$$

$$\text{StateDist2} = \text{sd}(\text{Current State}, \text{BB-Intercept}_{\text{B-Zone}})$$

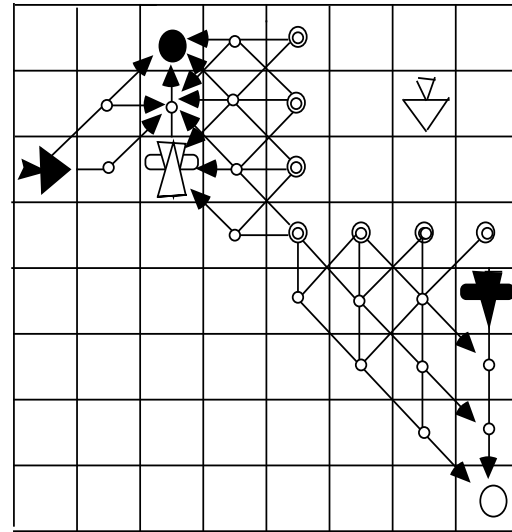
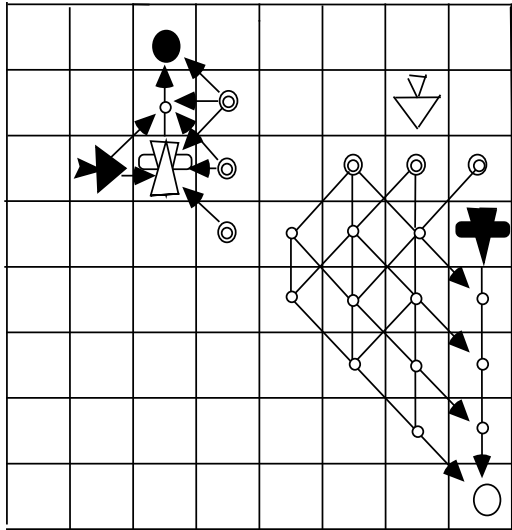
$$\text{StateDist} = \text{StateDist1} + \text{StateDist2}$$

$$\text{StateDist} \geq \text{sd}(\text{Current State}, \text{WB-Protect}_{\text{W-Zone}} \cup \text{BB-Intercept}_{\text{B-Zone}})$$



StateDist = 5

StateDist= 4



StateDist = 4

Strategy at the Start State

White follows Mixed Draw strategy while Black follows B-Win strategy

