

Series Editor
Jean-Charles Pomerol

Distributed Systems

Concurrency and Consistency

Mathieu Perrin

Color section

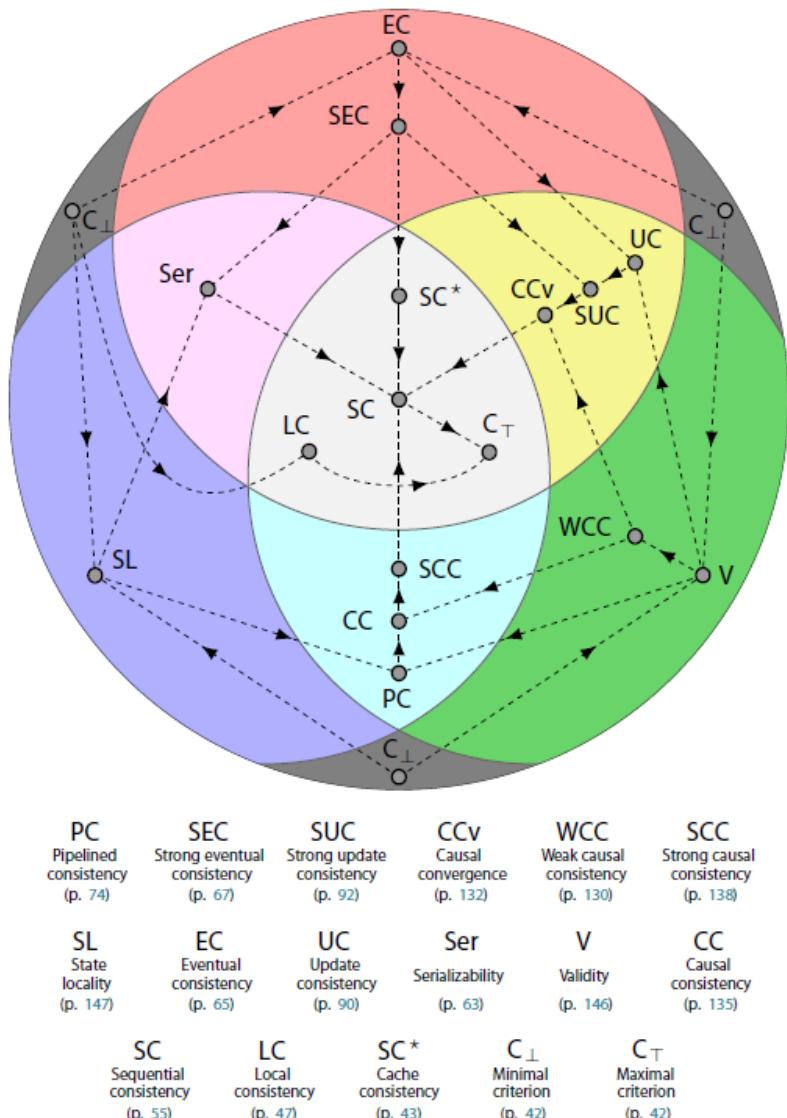


Figure I.5. Map of the consistency criteria discussed in this book

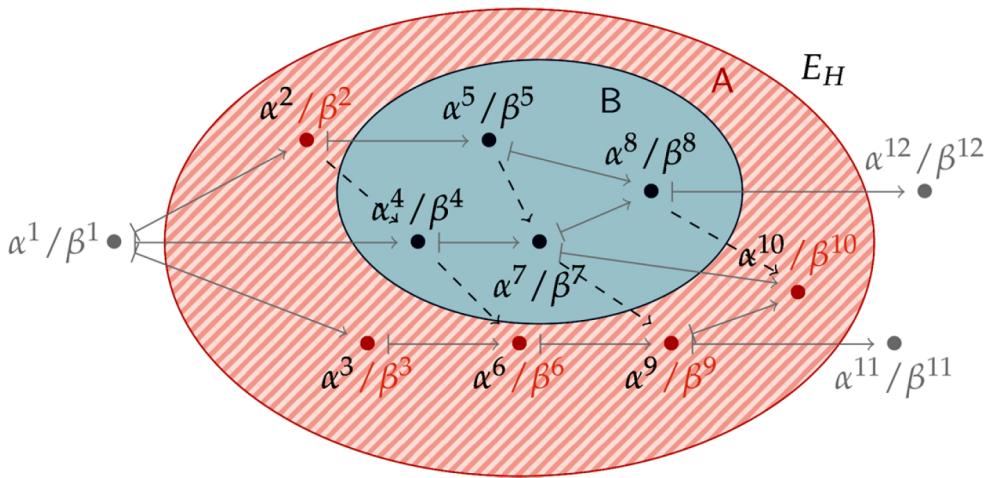
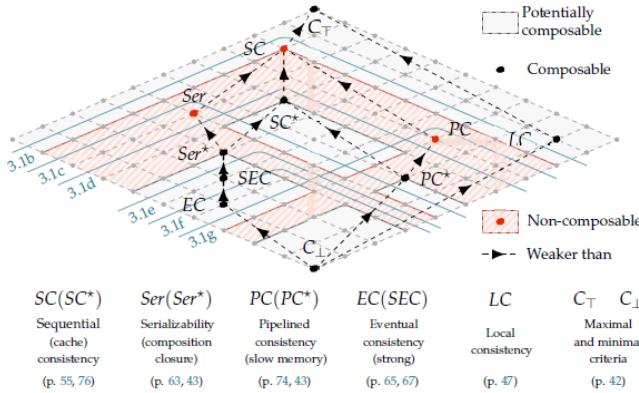
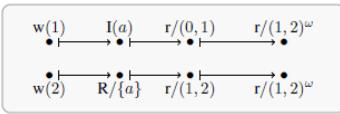


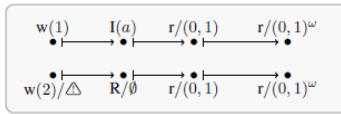
Figure 1.6. $H''[A/B]$ contains the updates of A and the queries of $A \cup B$



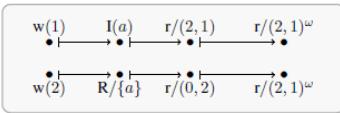
a) Consistency criteria lattice.



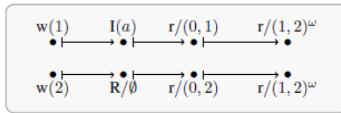
b) SC



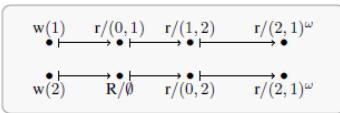
c) Ser but not SC^* nor PC^*



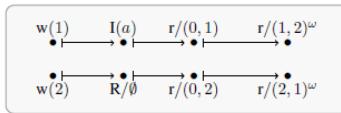
d) SC^* but not Ser nor PC



e) SEC but not Ser^* nor PC^*



f) EC but not SEC nor PC^*



g) PC but not EC

Figure 2.1. Histories illustrating various consistency criteria

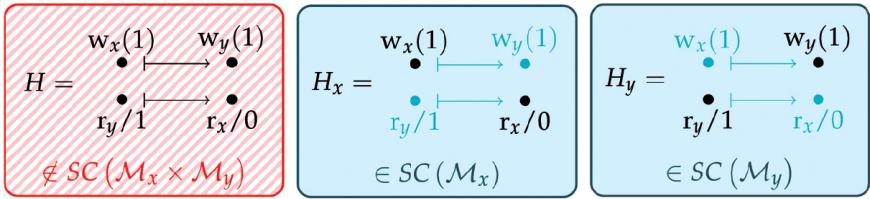


Figure 2.5. Sequential consistency is not composable

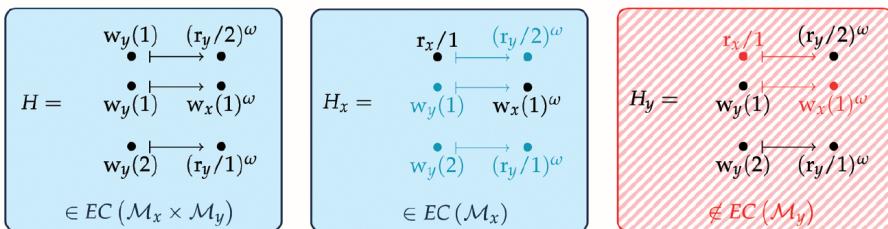
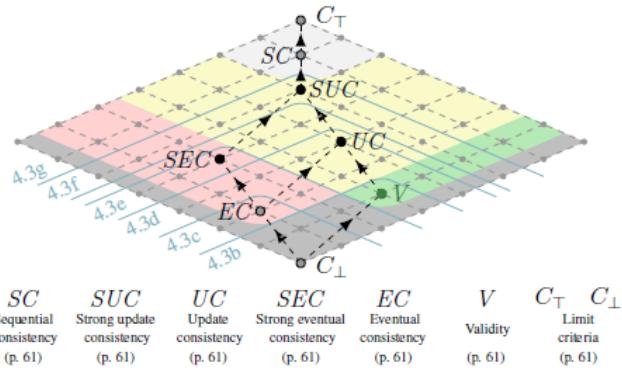
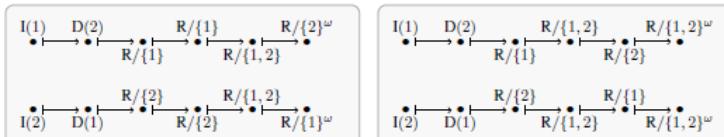


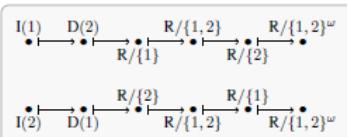
Figure 2.11. Eventual consistency is not decomposable



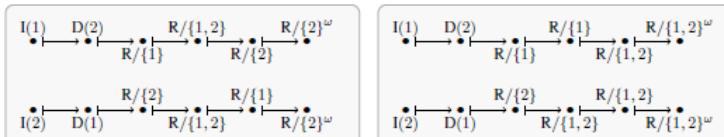
a) Relative strength of update consistency



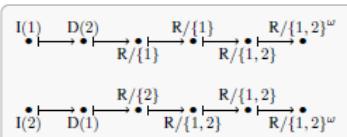
b) Not EC



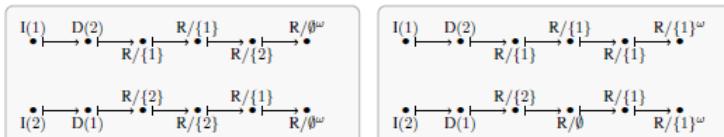
c) EC but not UC nor SEC



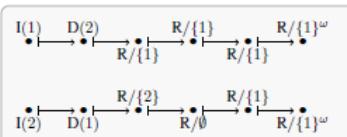
d) UC but not SEC



e) SEC but not UC

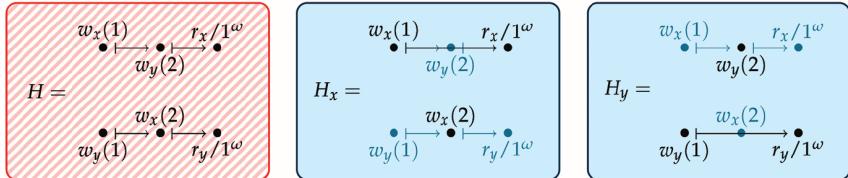


f) UC and SEC but not SUC

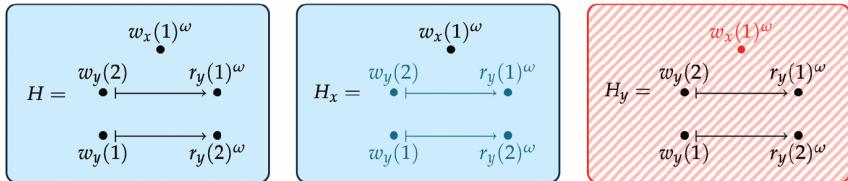


g) SUC but not SC

Figure 3.3. Examples of histories for update consistency



(a) Lack of compositability: $H_x \in UC(\mathcal{M}_x)$ and $H_y \in UC(\mathcal{M}_y)$ but $H \notin UC(\mathcal{M}_{\{x,y\}})$



(b) Lack of decomposability: $H \in UC(\mathcal{M}_{\{x,y\}})$ but $H_y \notin UC(\mathcal{M}_y)$

Figure 3.4. Update consistency is neither composable nor decomposable

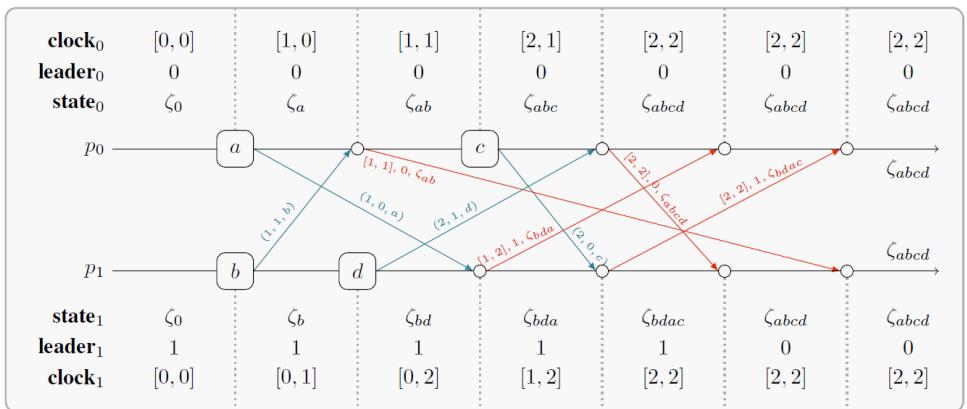
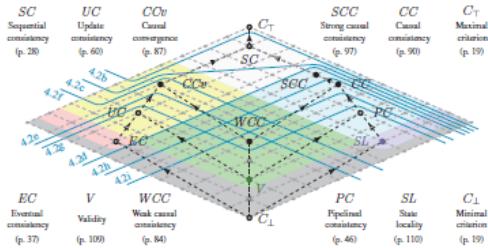


Figure 3.10. Execution example of the UC_o algorithm

sent₀	false	false	false	false	false	true
leader₀	0	0	0	0	0	0
rclock₀	[0, 0]	[0, 0]	[0, 0]	[1, 1]	[1, 1]	[1, 1]
rvtime₀	0	0	0	1	1	1
rstate₀	ζ_0	ζ_0	ζ_0	ζ_{ab}	ζ_{ab}	ζ_{ab}
vtime₀	0	1	1	2	2	2
history₀	[]	$[(1, 0, a)]$	$\begin{bmatrix} (1, 0, a) \\ (1, 1, b) \end{bmatrix}$	$[(2, 0, c)]$	$\begin{bmatrix} (2, 0, c) \\ (2, 1, d) \end{bmatrix}$	$\begin{bmatrix} (2, 0, c) \\ (2, 1, d) \end{bmatrix}$
history₁	[]	$[(1, 1, b)]$	$[(2, 1, d)]$	$[(2, 1, d)]$	$\begin{bmatrix} (2, 0, c) \\ (2, 1, d) \end{bmatrix}$	$\begin{bmatrix} (2, 0, c) \\ (2, 1, d) \end{bmatrix}$
vtime₁	0	1	2	2	2	2
rstate₁	ζ_0	ζ_0	ζ_b	ζ_{ba}	ζ_{ba}	ζ_{ab}
rvtime₁	0	0	1	1	1	1
rclock₁	[0, 0]	[0, 0]	[0, 1]	[1, 1]	[1, 1]	[1, 1]
leader₁	1	1	1	1	1	0
sent₁	false	false	false	true	false	true

Figure 3.13. Execution example of the UC[k] algorithm



a) Relative force of the different causal criteria

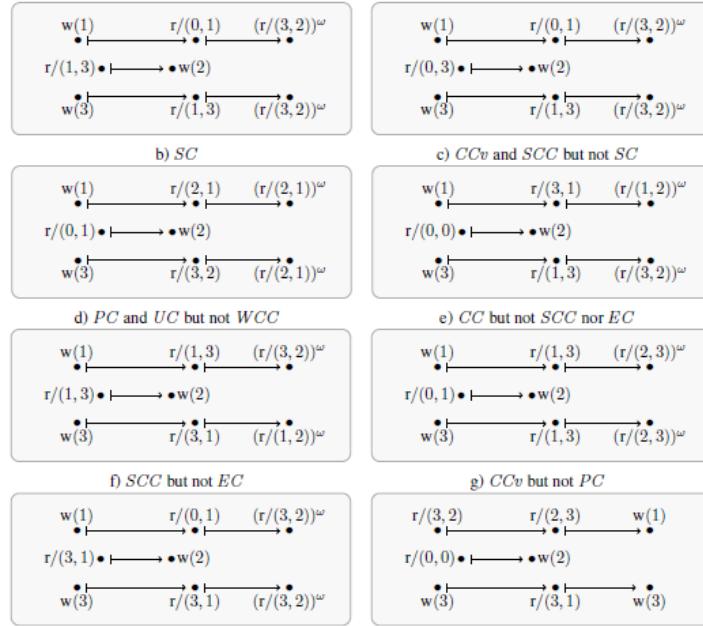


Figure 4.2. Relative force of causal criteria

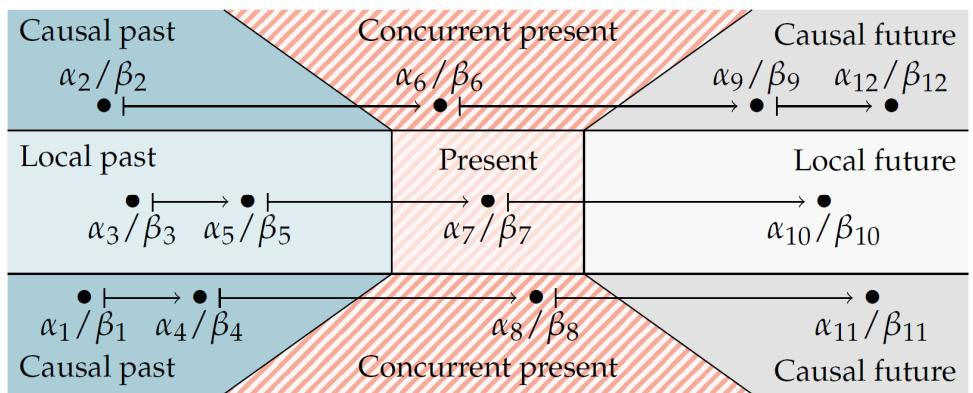
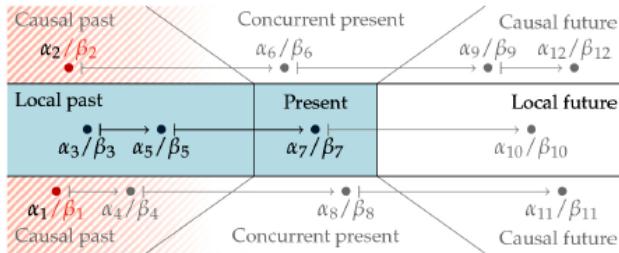
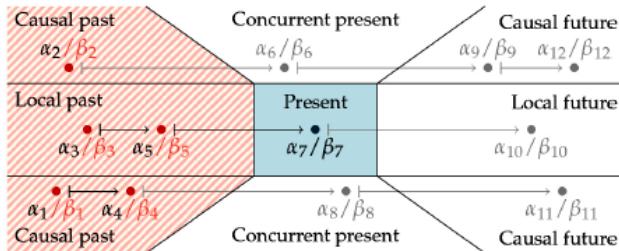


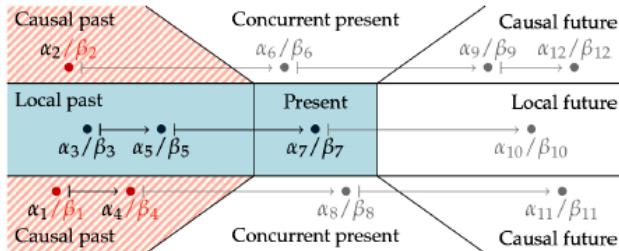
Figure 4.3. Temporal zones defined by the causal order



(a) Pipelined consistency (PC).



(b) Weak causal consistency (WCC).

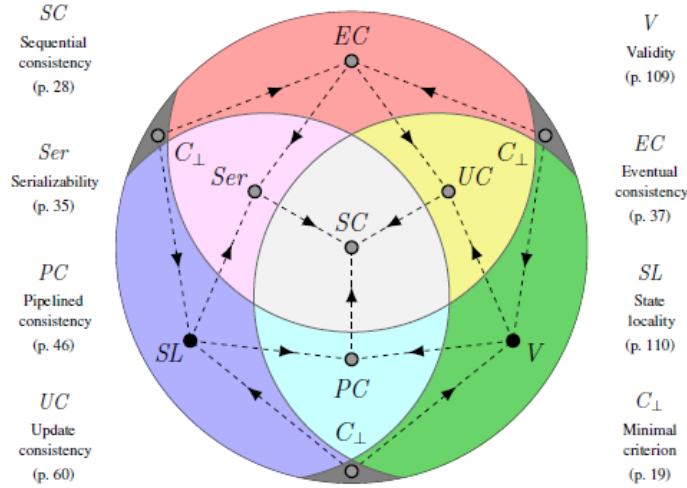


(c) Causal consistency (CC).

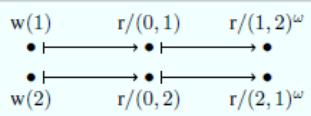
Only the reads influence the present

Both reads and writes influence the present

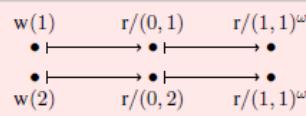
Figure 4.8. Consistency criteria using the six temporal zones



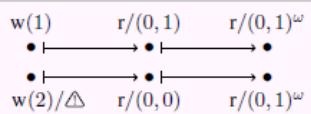
a) Spatial structure of weak criteria



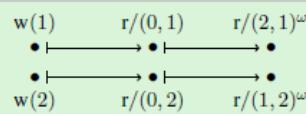
b) Pipelined consistency



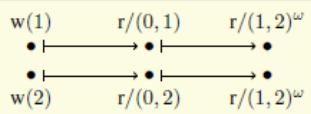
c) Eventual consistency



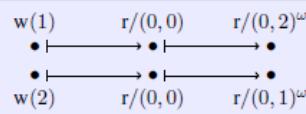
d) Serializability



e) Validity



f) Update consistency



g) State locality

Figure 5.1. The three paths of weak consistency applied to the object W_2

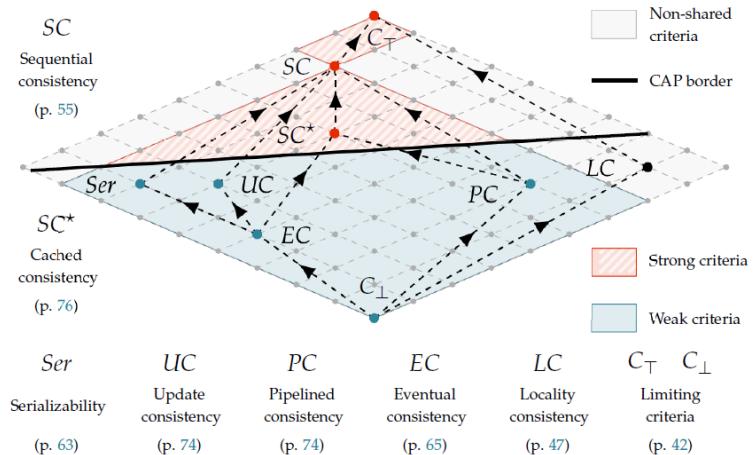


Figure 5.2. Consistency criteria lattice

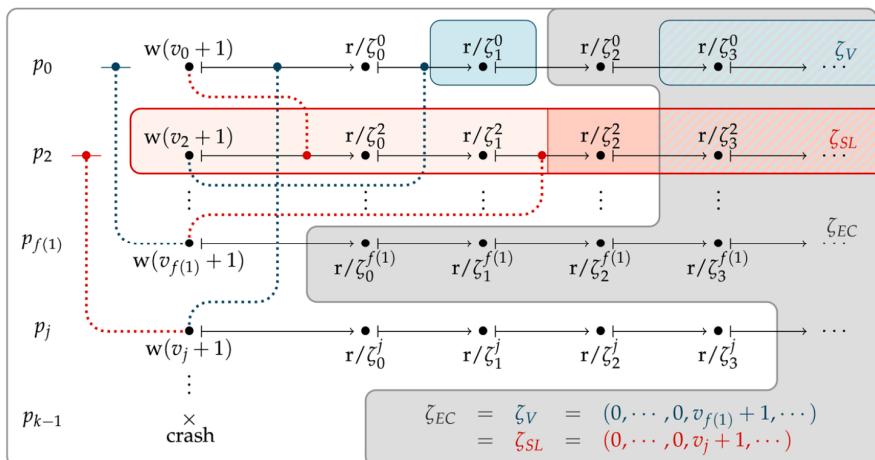


Figure 5.6. Extension of the history produced by the algorithm in Figure 5.5

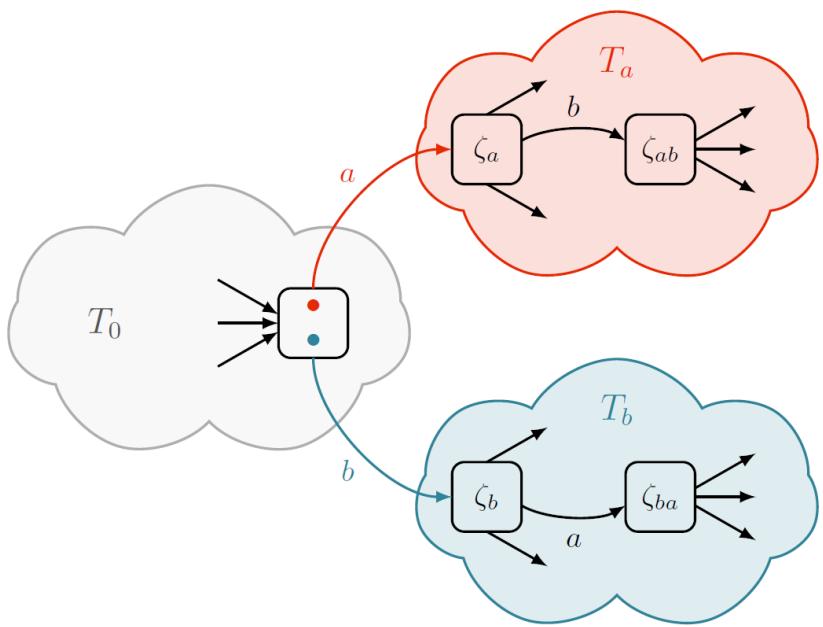


Figure 5.7. Explanation of the structure of weak criteria space

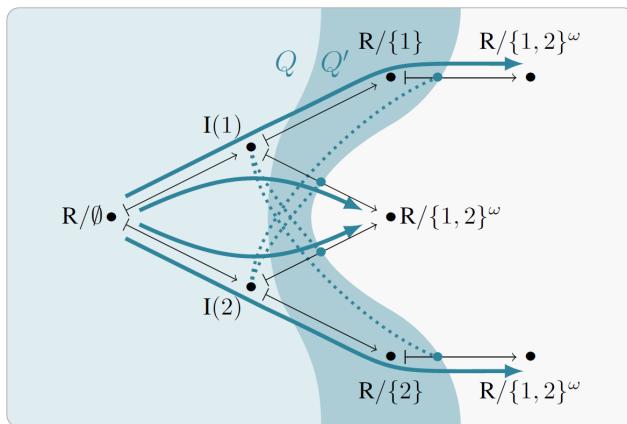
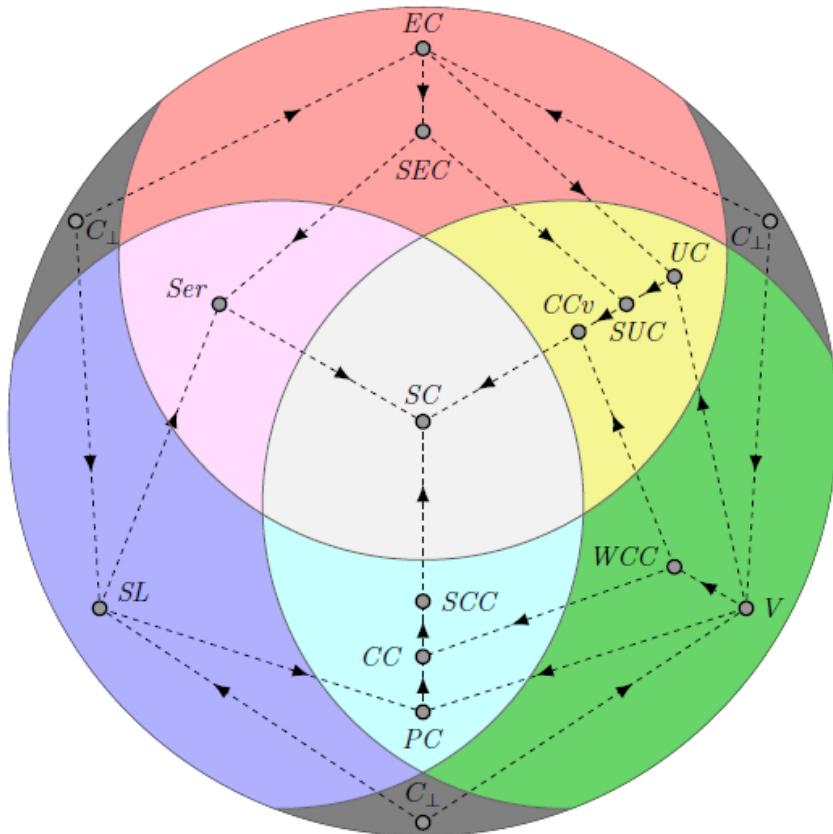


Figure 5.9. For CADTs pipelined consistency implies eventual consistency



SC Sequential Consistency (p. 28)	PC Pipelined Consistency (p. 46)	SEC Strong Eventual Consistency (p. 39)	EC Eventual Consistency (p. 37)	CCv Causal Convergence (p. 87)	WCC Weak Causal Consistency (p. 84)	SCC Strong Causal Consistency (p. 97)
C_{\perp} Minimal Criterion (p. 19)	SL State Locality (p. 110)	SUC Strong Update Consistency (p. 61)	UC Update Consistency (p. 60)	Ser Serializability (p. 35)	V Validity (p. 109)	CC Causal Consistency (p. 90)

Figure 1. Mapping weak criteria space