

# BFO 2020 Spatiotemporal Axioms

(1) Exists at is a lower bound on first argument

$$\forall p,q,r (\text{existsAt}(p,q) \wedge \text{temporalPartOf}(p,r) \rightarrow \text{existsAt}(r,q))$$

(2) Occupies temporal region is functional on second argument

$$\forall p,q,r (\text{occupiesTemporalRegion}(p,q) \wedge \text{occupiesTemporalRegion}(p,r) \rightarrow q=r)$$

(3) Spatially projects onto is time indexed and has domain: spatiotemporal region and range: spatial region

$$\begin{aligned} \forall a,b,t (\text{spatiallyProjectsOnto}(a,b,t) \\ \rightarrow \text{instanceOf}(a,\text{spatiotemporalRegion},t) \wedge \text{instanceOf}(b,\text{spatialRegion},t) \\ \wedge \text{instanceOf}(t,\text{temporalRegion},t)) \end{aligned}$$

(4) Process p (or boundary) occupies spatiotemporal region st iff every part of p occupies spatiotemporal region a part of st, and there isn't a smaller part of st that p occupies.

$$\begin{aligned} \forall o,st ((\exists t1 \text{instanceOf}(o,\text{process},t1) \vee \exists t1 \text{instanceOf}(o,\text{processBoundary},t1)) \\ \wedge \exists t1 \text{instanceOf}(st,\text{spatiotemporalRegion},t1) \\ \rightarrow (\text{occupiesSpatiotemporalRegion}(o,st) \\ \leftrightarrow (\forall op (\text{occurentPartOf}(op,o) \\ \rightarrow \forall stp (\text{occupiesSpatiotemporalRegion}(op,stp) \\ \rightarrow \text{occurentPartOf}(stp,st)))))) \\ \wedge \neg(\exists st' (st' \neq st \wedge \text{occurentPartOf}(st',st) \\ \wedge \text{occupiesSpatiotemporalRegion}(o,st')))) \end{aligned}$$

(5) Occurs in is a lower bound on second argument

$$\forall p,c1,c2 (\text{occursIn}(p,c1) \wedge (\forall t (\text{existsAt}(p,t) \leftrightarrow \text{locatedIn}(c1,c2,t))) \rightarrow \text{occursIn}(p,c2))$$

(6) If one occurrent is part of another, then the temporal region of the first is part of the temporal region of the second

$$\begin{aligned} \forall o1,o2,t1,t2 ((\exists t (\text{instanceOf}(o1,\text{process},t) \vee \text{instanceOf}(o1,\text{processBoundary},t)) \\ \wedge \exists t \text{instanceOf}(o2,\text{process},t) \wedge \text{occurentPartOf}(o1,o2) \\ \wedge \text{occupiesTemporalRegion}(o1,t1) \wedge \text{occupiesTemporalRegion}(o2,t2) \\ \rightarrow \text{temporalPartOf}(t1,t2)) \end{aligned}$$

(7) If something occupies a temporal region, then it exists at that region

$$\forall a,t (\text{occupiesTemporalRegion}(a,t) \rightarrow \text{existsAt}(a,t))$$

(8) Process or process boundary p occupies temporal region t iff every part of p temporally occupies a part of t, and there isn't a smaller part of t that p occupies.

$$\begin{aligned} \forall o,t ((\exists t1 \text{instanceOf}(o,\text{process},t1) \vee \exists t1 \text{instanceOf}(o,\text{processBoundary},t1)) \\ \wedge \text{instanceOf}(t,\text{temporalRegion},t) \\ \rightarrow (\text{occupiesTemporalRegion}(o,t) \\ \leftrightarrow (\forall op (\text{occurentPartOf}(op,o) \\ \rightarrow \forall tp (\text{occupiesTemporalRegion}(op,tp) \rightarrow \text{occurentPartOf}(tp,t)))) \\ \wedge \neg(\exists t' (t' \neq t \wedge \text{occurentPartOf}(t',t) \\ \wedge \text{occupiesTemporalRegion}(o,t')))) \end{aligned}$$

(9) The temporal region during which a process occurs is the same as that which the spatiotemporal region the process occupies temporally projects onto

$$\begin{aligned} \forall p,t (\text{occupiesTemporalRegion}(p,t) \\ \leftrightarrow \exists st (\text{occupiesSpatiotemporalRegion}(p,st) \wedge \text{temporallyProjectsOnto}(st,t))) \end{aligned}$$

(10) Temporally projects onto is functional on second argument

$$\forall p,q,r (\text{temporallyProjectsOnto}(p,q) \wedge \text{temporallyProjectsOnto}(p,r) \rightarrow q=r)$$

(11) Every temporal region is a projection from a spatiotemporal region

$$\begin{aligned} \forall tr (\exists t \text{instanceOf}(tr,\text{temporalRegion},t) \\ \rightarrow \exists st (\exists t \text{instanceOf}(st,\text{spatiotemporalRegion},t) \wedge \text{temporallyProjectsOnto}(st,tr))) \end{aligned}$$

(12) Occupies temporal region has domain process or process boundary and range temporal region

$$\begin{aligned} &\forall a,b (\text{occupiesTemporalRegion}(a,b) \\ &\rightarrow (\exists t (\text{instanceOf}(a,\text{process},t) \vee \text{instanceOf}(a,\text{processBoundary},t))) \\ &\wedge \exists t \text{instanceOf}(b,\text{temporalRegion},t)) \end{aligned}$$

(13) Spatiotemporal regions always project on to some temporal region

$$\begin{aligned} &\forall st (\exists t \text{instanceOf}(st,\text{spatiotemporalRegion},t) \\ &\rightarrow \exists t (\text{instanceOf}(t,\text{temporalRegion},t) \wedge \text{temporallyProjectsOnto}(st,t))) \end{aligned}$$

(14) If one process or process boundary is part of another, then their corresponding temporal regions are also in a parthood relation

$$\begin{aligned} &\forall o1,o2,st1,st2 ((\exists t (\text{instanceOf}(o1,\text{process},t) \vee \text{instanceOf}(o1,\text{processBoundary},t))) \\ &\wedge (\exists t (\text{instanceOf}(o2,\text{process},t) \vee \text{instanceOf}(o2,\text{processBoundary},t))) \\ &\wedge \text{occurrentPartOf}(o1,o2) \wedge \text{occupiesSpatiotemporalRegion}(o1,st1) \\ &\wedge \text{occupiesSpatiotemporalRegion}(o2,st2) \\ &\rightarrow \text{occurrentPartOf}(st1,st2)) \end{aligned}$$

(15) Occupies spatiotemporal region has domain process or process boundary and range spatiotemporal region

$$\begin{aligned} &\forall a,b (\text{occupiesSpatiotemporalRegion}(a,b) \\ &\rightarrow (\exists t (\text{instanceOf}(a,\text{process},t) \vee \text{instanceOf}(a,\text{processBoundary},t))) \\ &\wedge \exists t \text{instanceOf}(b,\text{spatiotemporalRegion},t)) \end{aligned}$$

(16) Occupies spatiotemporal region is functional on second argument

$$\forall p,q,r (\text{occupiesSpatiotemporalRegion}(p,q) \wedge \text{occupiesSpatiotemporalRegion}(p,r) \rightarrow q=r)$$

(17) A process occupies at least a temporal interval

$$\begin{aligned} &\forall \text{proc},tr (\exists t \text{instanceOf}(\text{proc},\text{process},t) \wedge \text{occupiesTemporalRegion}(\text{proc},tr) \\ &\rightarrow \exists \text{interval} (\text{instanceOf}(\text{interval},\text{temporalInterval},\text{interval}) \\ &\wedge \text{temporalPartOf}(\text{interval},tr))) \end{aligned}$$

(18) If a process or process boundary is part of another, their spatiotemporal regions are part too

$$\begin{aligned} &\forall p1,p2 ((\exists t \text{instanceOf}(p1,\text{process},t) \vee \exists t \text{instanceOf}(p1,\text{processBoundary},t)) \\ &\wedge (\exists t \text{instanceOf}(p2,\text{process},t) \vee \exists t \text{instanceOf}(p2,\text{processBoundary},t)) \\ &\rightarrow (\text{occurrentPartOf}(p1,p2) \\ &\leftrightarrow \exists st1,st2 (\text{occupiesSpatiotemporalRegion}(p1,st1) \\ &\wedge \text{occupiesSpatiotemporalRegion}(p2,st2) \\ &\wedge \text{occurrentPartOf}(st1,st2)))))) \end{aligned}$$

(19) A process boundary occupies a spatiotemporal instant

$$\begin{aligned} &\forall pb,tr (\exists t \text{instanceOf}(pb,\text{processBoundary},t) \wedge \text{occupiesTemporalRegion}(pb,tr) \\ &\rightarrow \text{instanceOf}(tr,\text{temporalInstant},tr)) \end{aligned}$$

(20) Temporally projects onto has domain spatiotemporal region and range temporal region

$$\begin{aligned} &\forall a,b (\text{temporallyProjectsOnto}(a,b) \\ &\rightarrow \exists t \text{instanceOf}(a,\text{spatiotemporalRegion},t) \wedge \exists t \text{instanceOf}(b,\text{temporalRegion},t)) \end{aligned}$$

(21) If a occupies spatial region b then if a is an instance of site then b is an instance of three dimensional spatial region

$$\begin{aligned} &\forall p,q,t (\text{occupiesSpatialRegion}(p,q,t) \wedge \text{instanceOf}(p,\text{site},t) \\ &\rightarrow \text{instanceOf}(q,\text{threeDimensionalSpatialRegion},t)) \end{aligned}$$

(22) Spatiotemporal regions always project on to some spatial region at any time

$$\begin{aligned} &\forall st,t (\text{instanceOf}(st,\text{spatiotemporalRegion},t) \\ &\rightarrow \exists s,tp (\text{temporalPartOf}(tp,t) \wedge \text{instanceOf}(s,\text{spatialRegion},tp) \\ &\wedge \text{spatiallyProjectsOnto}(st,s,tp))) \end{aligned}$$

(23) Spatially projects onto is functional on second argument

$$\forall p,q,r,s (\text{spatiallyProjectsOnto}(p,q,r) \wedge \text{spatiallyProjectsOnto}(p,s,r) \rightarrow q=s)$$

(24) Every spatial region is a projection from a spatiotemporal region

$$\begin{aligned} &\forall sr (\exists t \text{instanceOf}(sr,\text{spatialRegion},t) \\ &\rightarrow \exists st (\exists t \text{instanceOf}(st,\text{spatiotemporalRegion},t) \wedge \exists t \text{spatiallyProjectsOnto}(st,sr,t))) \end{aligned}$$

(25) For every process there's a corresponding spatiotemporal region

$$\begin{aligned} &\forall p (\exists t (\text{instanceOf}(p,\text{process},t) \vee \text{instanceOf}(p,\text{processBoundary},t)) \\ &\rightarrow \exists s \text{occupiesSpatiotemporalRegion}(p,s)) \end{aligned}$$