BFO 2020 Spatial Axioms

Occurs in and environs are inverse relations [uys-1]

$$\forall a,b\,(\mathrm{occursIn}(a,b) \leftrightarrow \mathrm{environs}(b,a))$$

Located in and location of are inverse relations [kaw-1]

$$\forall t,a,b\,(\mathrm{locatedIn}(a,b,t) \leftrightarrow \mathrm{locationOf}(b,a,t))$$

Occurs in is dissective on first argumentwhen it is an occurrent [jil-1]

$$\forall p,q,r\,(\mathrm{occursIn}(p,q) \land \mathrm{occurrentPartOf}(r,p) \rightarrow \mathrm{occursIn}(r,q))$$

If a process (or process boundary) occurs in a continuant, that continuant exists at least as long as the process does [dxv-1]

$$\forall p,c\,(\mathrm{occursIn}(p,c) \rightarrow \forall t\,(\mathrm{existsAt}(p,t) \rightarrow \mathrm{existsAt}(c,t)))$$

Located in is dissective on third argument, a temporal region [put-1]

$$\forall p,q,r,s\,(\mathrm{locatedIn}(p,q,r) \land \mathrm{temporalPartOf}(s,r) \rightarrow \mathrm{locatedIn}(p,q,s))$$

Located in is a lower bound on second argument [evu-1]

$$\forall p,q,r,s\,(\mathrm{locatedIn}(p,q,r) \land \mathrm{continuantPartOf}(q,s,r) \rightarrow \mathrm{locatedIn}(p,s,r))$$

Located in is dissective on first argumentwhen it is a continuant [wty-1]

$$\forall p,q,r,s\,(\mathrm{locatedIn}(p,q,r) \land \mathrm{continuantPartOf}(s,p,r) \rightarrow \mathrm{locatedIn}(s,q,r))$$

Occupies spatial region is functional on second argument [zls-1]

$$\forall p,q,r,s\,(\mathrm{occupiesSpatialRegion}(p,q,r) \land \mathrm{occupiesSpatialRegion}(p,s,r) \rightarrow q=s)$$

Occupies spatial region is dissective on third argument, a temporal region [mud-1]

$$\forall p,q,r,s\,(\mathrm{occupiesSpatialRegion}(p,q,r) \land \mathrm{temporalPartOf}(s,r) \\ \rightarrow \mathrm{occupiesSpatialRegion}(p,q,s))$$

Spatially projects onto is dissective on third argument, a temporal region [ivt-1]

$$\forall p,q,r,s\,(\mathrm{spatiallyProjectsOnto}(p,q,r) \land \mathrm{temporalPartOf}(s,r) \\ \rightarrow \mathrm{spatiallyProjectsOnto}(p,q,s))$$

Located in is transitive at a time [ets-1]

$$\forall a,b,c,t,t2\,(\mathrm{locatedIn}(a,b,t) \land \mathrm{locatedIn}(b,c,t2) \land \mathrm{temporalPartOf}(t,t2) \\ \rightarrow \mathrm{locatedIn}(a,c,t))$$

If a location of b then if a is an instance of continuant fiat boundary then b is an instance of continuant fiat boundary [wte-1]

$$\forall p,q,t\,(\mathrm{locationOf}(p,q,t) \land \mathrm{instanceOf}(p,\mathrm{continuantFiatBoundary},t) \\ \rightarrow \mathrm{instanceOf}(q,\mathrm{continuantFiatBoundary},t))$$

All spatial regions are part of a 3 dimensional spatial region [xcx-1]

$$\forall s,t\,(\mathrm{instanceOf}(s,\mathrm{spatialRegion},t) \\ \rightarrow \exists s3\,(\mathrm{instanceOf}(s3,\mathrm{threeDimensionalSpatialRegion},t) \land \mathrm{continuantPartOf}(s,s3,t)))$$

Occurs in is lower bound location [czc-1]

$$\forall p,c1,c2\,(\mathrm{occursIn}(p,c1) \\ \land (\forall t\,(\mathrm{existsAt}(p,t) \leftrightarrow \mathrm{existsAt}(c2,t) \land \mathrm{continuantPartOf}(c1,c2,t))) \\ \rightarrow \mathrm{occursIn}(p,c2))$$

If something is located in something else then the region of the first is part of the region of the second [uas-1]

$$\forall a,b,t\,(\mathrm{locatedIn}(a,b,t) \\ \rightarrow \exists r1,r2,t2\,(\mathrm{temporalPartOf}(t2,t) \land \mathrm{occupiesSpatialRegion}(a,r1,t2) \\ \land \mathrm{occupiesSpatialRegion}(b,r2,t2) \land \mathrm{continuantPartOf}(r1,r2,t2)))$$

Occurs in has domain process or process boundary and range material entity or site [tfw-1]

$$\forall a,b\,(\mathrm{occursIn}(a,b) \\ \rightarrow (\exists t\,(\mathrm{instanceOf}(a,\mathrm{process},t) \lor \mathrm{instanceOf}(a,\mathrm{processBoundary},t))) \\ \land (\exists t\,(\mathrm{instanceOf}(b,\mathrm{materialEntity},t) \lor \mathrm{instanceOf}(b,\mathrm{site},t))))$$

Spatial regions don't change what they are part of. [mlb-1]

$$\forall s,sp\,(\exists t\,(\mathrm{instanceOf}(s,\mathrm{spatialRegion},t) \land \mathrm{continuantPartOf}(sp,s,t)) \\ \quad \rightarrow \forall t\,(\exists \mathrm{sPrime}\ \mathrm{continuantPartOf}(\mathrm{sPrime},s,t) \rightarrow \mathrm{continuantPartOf}(sp,s,t)))$$

Occupies spatial region is time indexed and has domain: independent continuant but not spatial region and range: spatial region [lzw-1]

$$\forall a,b,t\,(\mathrm{occupiesSpatialRegion}(a,b,t) \\ \quad \rightarrow \mathrm{instanceOf}(a,\mathrm{independentContinuant},t) \land \neg \mathrm{instanceOf}(a,\mathrm{spatialRegion},t) \\ \quad \land \mathrm{instanceOf}(b,\mathrm{spatialRegion},t) \land \mathrm{instanceOf}(t,\mathrm{temporalRegion},t))$$

If there are two independent continuants that are not spatial regions, and one is part of the other, then it is located in the other [bao-1]

$$\forall a,b,t\,(\mathrm{continuantPartOf}(a,b,t) \land \mathrm{instanceOf}(a,\mathrm{independentContinuant},t) \\ \quad \land \neg \mathrm{instanceOf}(a,\mathrm{spatialRegion},t) \land \mathrm{instanceOf}(b,\mathrm{independentContinuant},t) \\ \quad \land \neg \mathrm{instanceOf}(b,\mathrm{spatialRegion},t) \\ \quad \rightarrow \mathrm{locatedIn}(a,b,t))$$

Spatial region is the union of zero dimensional spatial region, one dimensional spatial region, two dimensional spatial region, and three dimensional spatial region [wnm-1]

$$\forall i,t\,(\mathrm{instanceOf}(i,\mathrm{spatialRegion},t) \\ \quad \rightarrow \mathrm{instanceOf}(i,\mathrm{zeroDimensionalSpatialRegion},t) \\ \quad \lor \mathrm{instanceOf}(i,\mathrm{oneDimensionalSpatialRegion},t) \\ \quad \lor \mathrm{instanceOf}(i,\mathrm{twoDimensionalSpatialRegion},t) \\ \quad \lor \mathrm{instanceOf}(i,\mathrm{threeDimensionalSpatialRegion},t))$$

No two material entities occupy the same space unless they coincide [scr-1]

$$\forall m1,m2,s,t\,(\mathrm{instanceOf}(m1,\mathrm{materialEntity},t) \land \mathrm{occupiesSpatialRegion}(m1,s,t) \\ \quad \land \mathrm{instanceOf}(m2,\mathrm{materialEntity},t) \land \mathrm{occupiesSpatialRegion}(m2,s,t) \\ \quad \rightarrow (\mathrm{continuantPartOf}(m2,m1,t) \land \mathrm{continuantPartOf}(m1,m2,t)) \lor m1=m2)$$

Located in is time indexed and has domain: independent continuant but not spatial region and range: independent continuant but not spatial region [bge-1]

$$\forall a,b,t\,(\mathrm{locatedIn}(a,b,t) \\ \quad \rightarrow \mathrm{instanceOf}(a,\mathrm{independentContinuant},t) \land \neg \mathrm{instanceOf}(a,\mathrm{spatialRegion},t) \\ \quad \land \mathrm{instanceOf}(b,\mathrm{independentContinuant},t) \land \neg \mathrm{instanceOf}(b,\mathrm{spatialRegion},t) \\ \quad \land \mathrm{instanceOf}(t,\mathrm{temporalRegion},t))$$

At all times t, there's a part of t when c occupies spatial region r iff every part of c occupies a part of r, and there isn't a smaller part of r that c occupies. [grv-1]

$$\forall c,r,t\,(\mathrm{instanceOf}(c,\mathrm{independentContinuant},t) \land \neg \mathrm{instanceOf}(c,\mathrm{spatialRegion},t) \\ \quad \land \mathrm{instanceOf}(r,\mathrm{spatialRegion},t) \\ \quad \rightarrow \exists t2\,(\mathrm{temporalPartOf}(t2,t) \\ \qquad \land (\mathrm{occupiesSpatialRegion}(c,r,t2) \\ \qquad\quad \leftrightarrow (\forall cp\,(\mathrm{continuantPartOf}(cp,c,t2) \\ \qquad\qquad \rightarrow \forall rp\,(\mathrm{occupiesSpatialRegion}(cp,rp,t2) \\ \qquad\qquad\quad \rightarrow \mathrm{continuantPartOf}(rp,r,t2)))) \\ \qquad\quad \land \neg(\exists r'\,(r' \neq r \land \mathrm{continuantPartOf}(r',r,t2) \\ \qquad\qquad \land \mathrm{occupiesSpatialRegion}(c,r',t2))))))$$

Alan Ruttenberg, January 8, 2024. The most recent version of this file will always be in the GitHub repository https://github.com/bfo-ontology/bfo-2020