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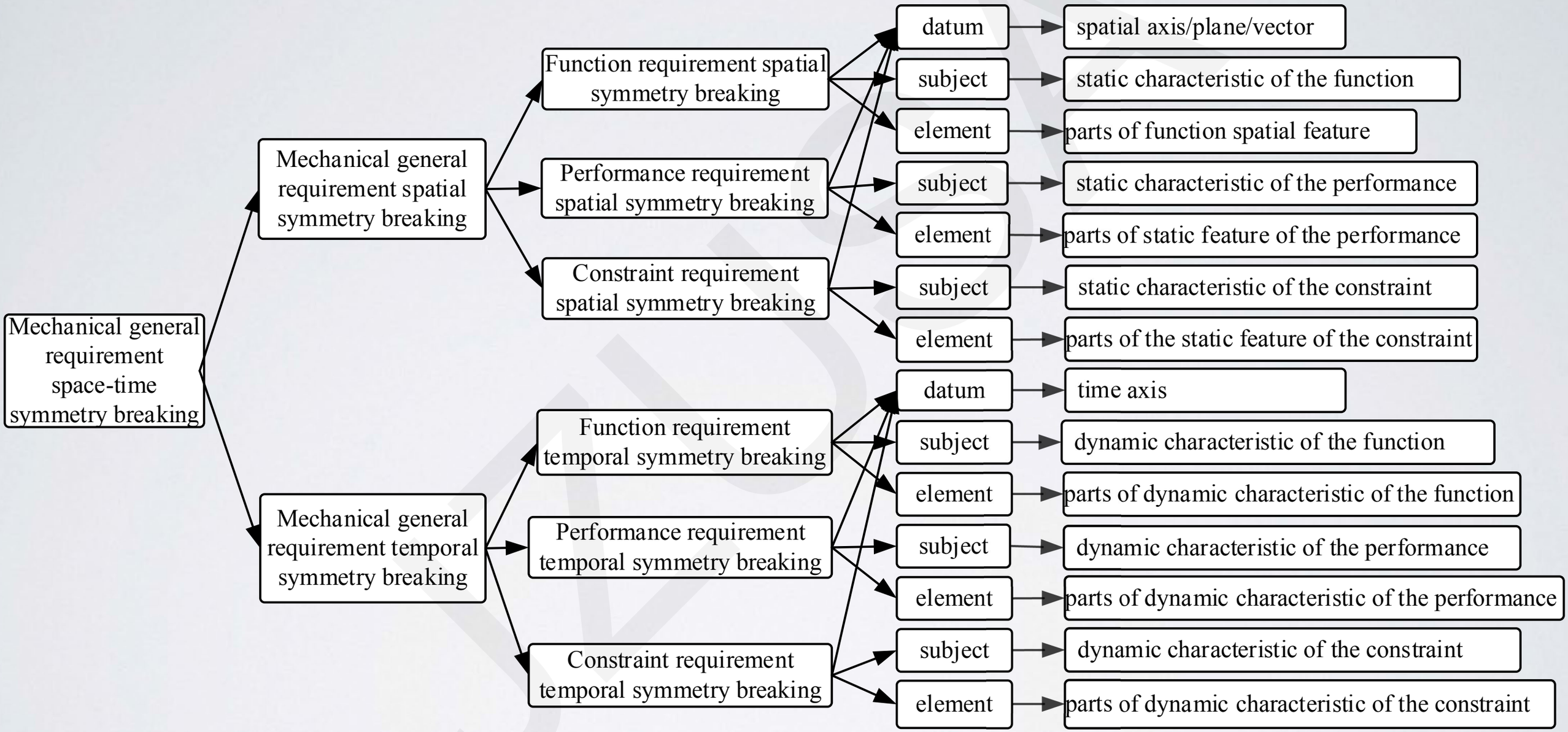
Framework of mechanical symmetry breaking theory and its application to innovative design

Key words:

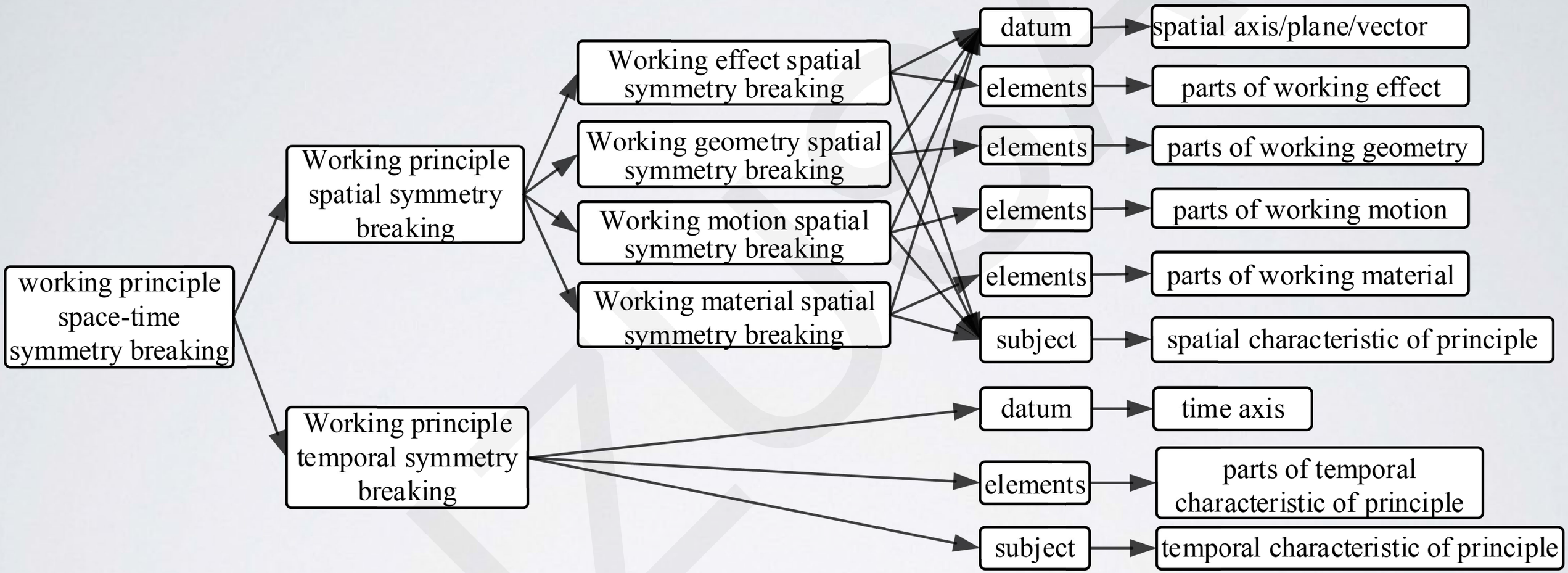
Mechanical symmetry breaking, Concept system, Design principle, Design method and process, Innovative instance

Concept system of mechanical space-time general requirement symmetry breaking



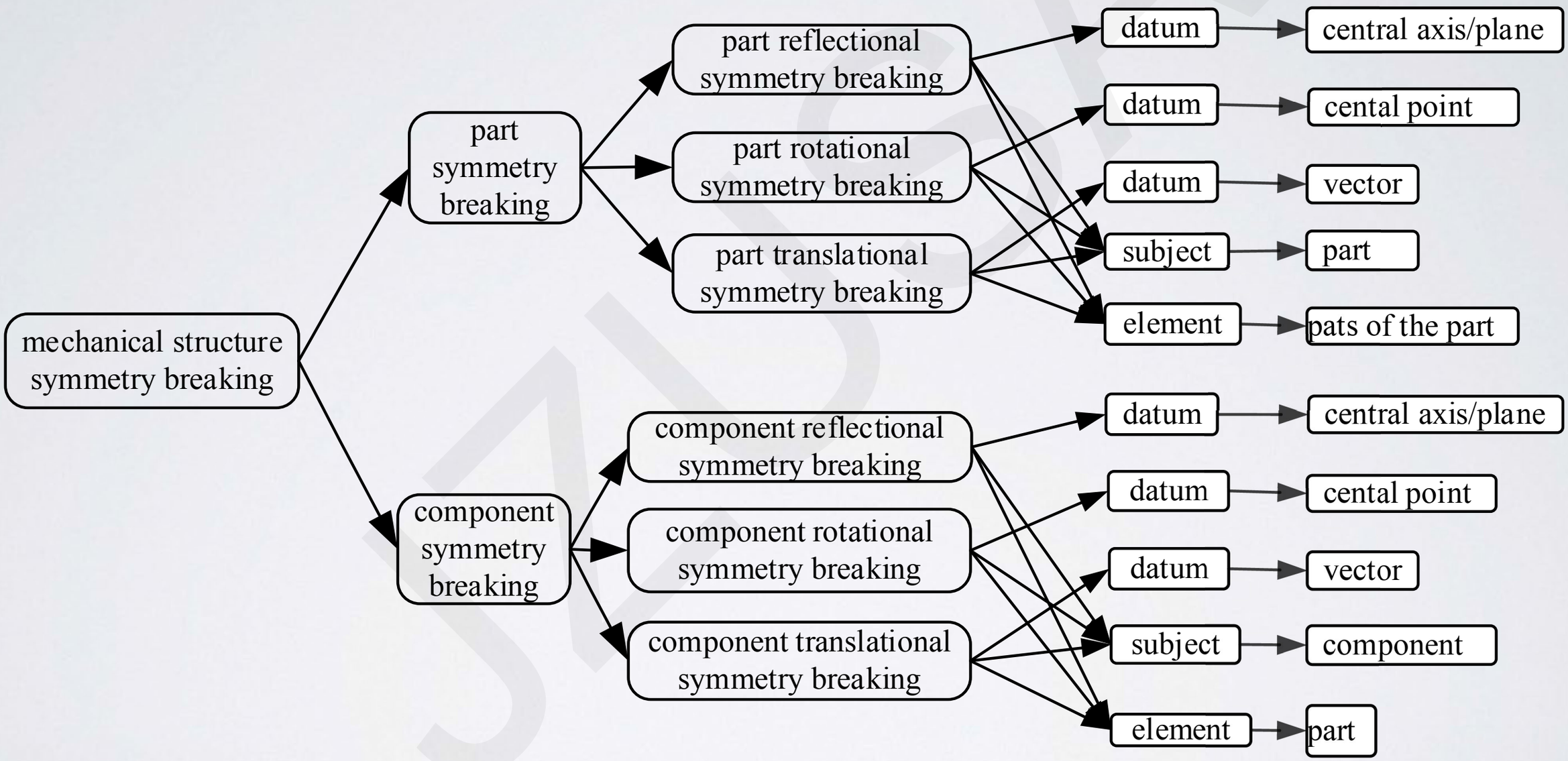
Mechanical general requirement space-time symmetry breaking refers to the objective requirements which possess features of symmetry breaking in space-time. The breaking subjects are product requirements, which consist of function requirements, performance requirements, and constraint requirements. The breaking elements are the components of a product's function, performance, or constraint requirement.

Concept system of working principle space-time symmetry breaking



Working principle space-time symmetry breaking means that the compositions of a solution have symmetry breaking features in the space or time datum. A working principle generally includes the working effect, working geometry, working motion and working material that are required to achieve a function. They are the physical feature parameters with which mechanical products achieve their general requirements

Concept system of mechanical structure symmetry breaking



The definition and classification of mechanical structure symmetry breaking can be expanded accordingly.

Correlations among mechanical general requirements, working principle and structure spatial symmetry breaking

1. Generally, structure spatial symmetry breaking is used to achieve principle spatial symmetry breaking, and principle spatial symmetry breaking is used to achieve function/performance spatial symmetry breaking. Therefore structure spatial symmetry breaking is a final way of achieving function/performance spatial symmetry breaking.

2. Spatial symmetry breaking of a constraint requirement typically leads to the symmetry breaking of a performance requirement. If the symmetry of structure or principle breaks, then the symmetry of performance requirements might be kept.

3. When a constraint requirement is symmetrical, or there is no constraint requirement, principle spatial symmetry may generally be used to obtain performance requirement spatial symmetry and principle spatial symmetry breaking may be used to obtain performance spatial symmetry breaking.

Regular knowledge on the application of symmetry breaking in design

■ **Using symmetry breaking to satisfy functional requirements of products**

1. Principle for achieving the variable speed function: For example, the rotational symmetry breaking of the structures of non-circular gears, sprockets and pulleys.

■ **Using symmetry breaking to satisfy performance requirements of products**

2. Principle for reducing the output fluctuation of a transmission system: If the dynamic output characteristic of each symmetry element is in phase, then the output fluctuation of a system will be reduced by making a phase difference for each element, i.e., changing the dimension, form or position parameters properly.

3. Principle to reduce collision and impact: The collision and impact between parts that are subjected to uniform loads can be reduced by breaking their symmetry that will make the forces exerted on the elements are different.

4. Principle for reducing system noise 1: Changing positional parameters of elements appropriately will make a phase difference in noise waves that will interfere and cancel each other. The total noise will be reduced.

5. Principle for reducing system noise 2: The sound frequency and magnitude generated by symmetrical elements are approximate, while the sound frequency and magnitude generated by symmetry breaking elements are quite different. Thus a symmetry breaking design can reduce noise level.

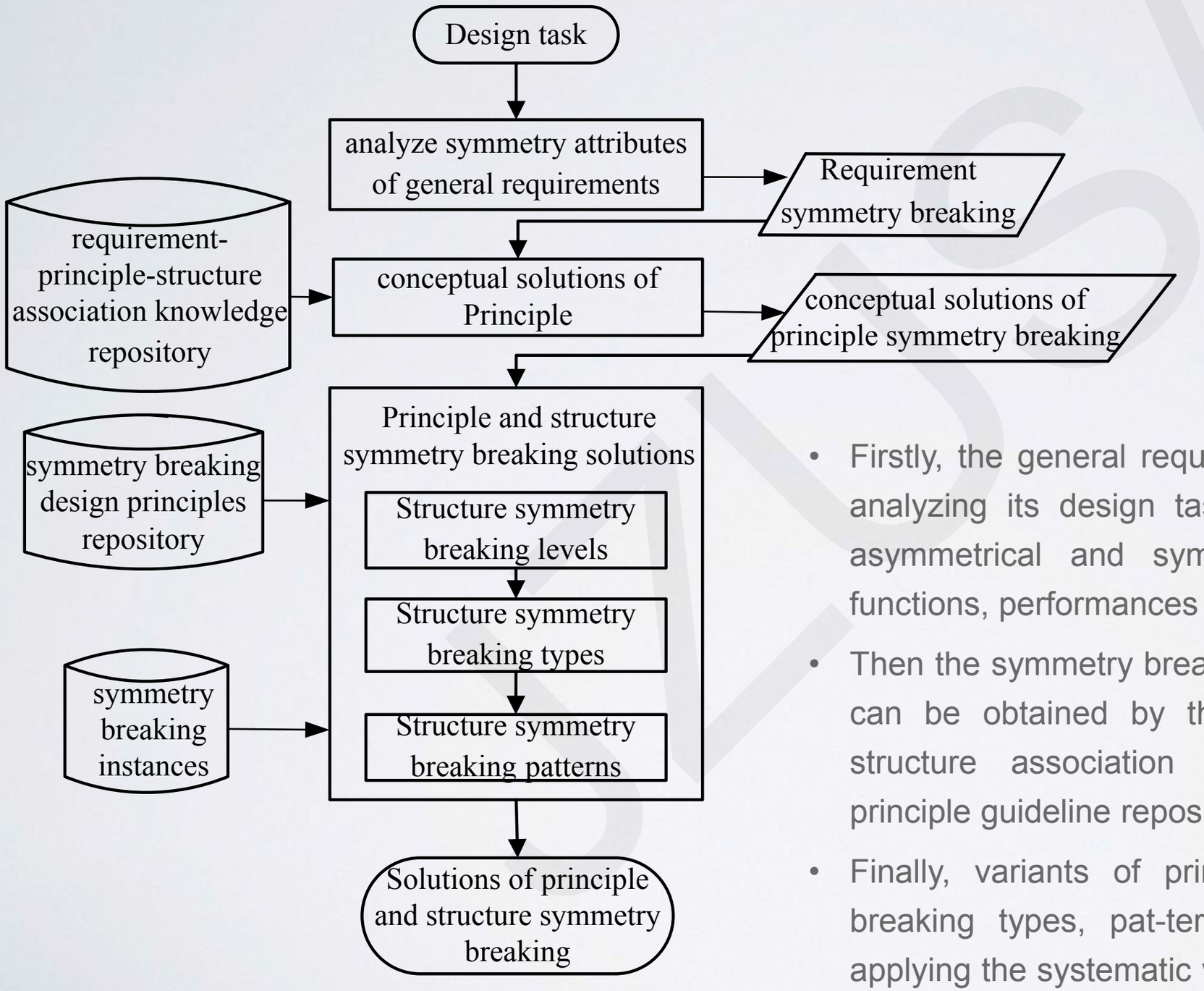
6. Principle of load match: When a structure-symmetrical system is subjected to asymmetrical loads, the element with the larger load can be broken and its bearing capacity made to match the load.

■ **Using symmetry to satisfy the constraint requirements of products**

7. Principle of increasing identification capability: Utilizing the geometrical difference of symmetry breaking elements will make the non-geometrical feature of a part easy to identify.

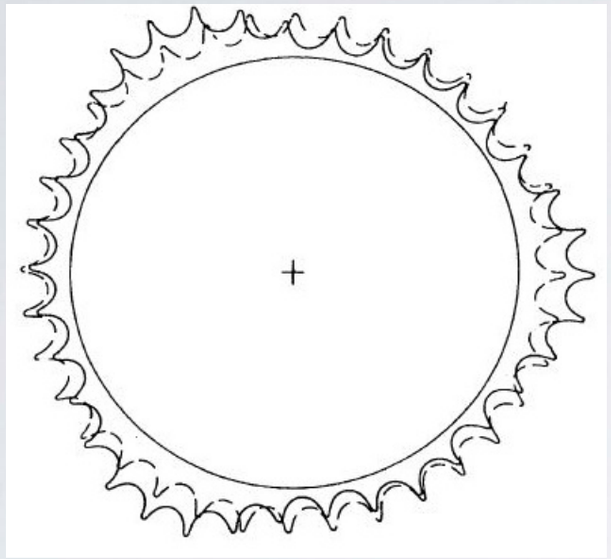
8. Principle of positioning during assembly: Symmetrical parts will be fitted in their unique assembly position if structure symmetry breaking is used.

Application method and process of symmetry breaking in mechanical concept design

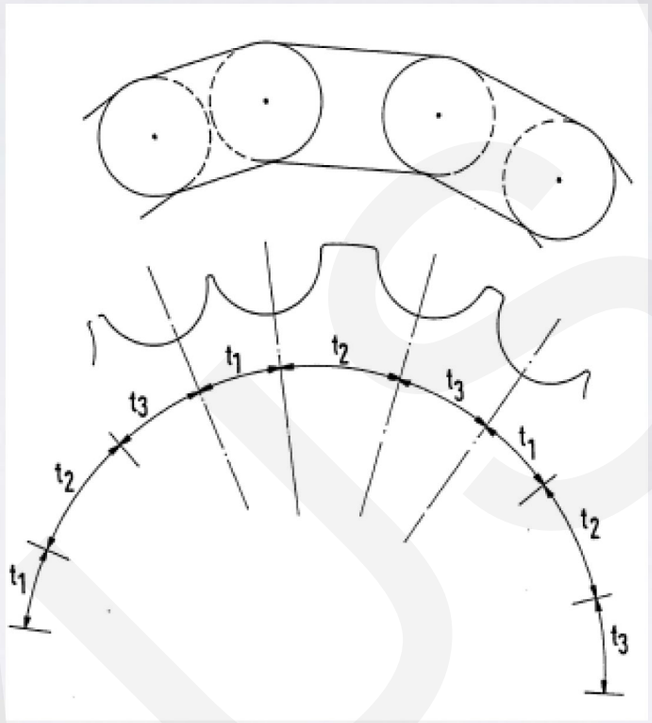


- Firstly, the general requirements of a product are specified by analyzing its design task, especially noting the symmetrical, asymmetrical and symmetry breaking requirements of its functions, performances and constraints.
- Then the symmetry breaking principle and/or structure solutions can be obtained by the aid of the “requirements-principle-structure association knowledge repository” and “design principle guideline repository”.
- Finally, variants of principle solutions in various symmetry breaking types, pat-terns and structures can be found by applying the systematic variation strategy for further comparison and selection.

Application method and process of symmetry breaking in mechanical concept design



(a) sprocket with unequal pitch



(b) chain with unequal pitch and sprocket

(c) a chain having unequal diameter rollers

A non-circular sprocket with different pitch radius might cause the vertical vibration of the chain and the processing of the non-circular contour is relatively difficult (Fig. a).

An unequal pitch chain drive unit might cause high impact and large fluctuation (Fig. b).

A chain comprised of rollers with different diameters is invented, which can reduce the fluctuation of the tensile force on the premise that the roller radius is smaller than the curvature radius. Its manufacturing difficulty is also less than the previous two ones (Fig. c).