Structural and Functional Representation of Grapevine Morphology in SysML

Dr Hlaszny, Edit[1] — Szilassy, Bertalan[1]

We present a new method in Systems Modeling Language[2] (SysML) to model both the internal structure and interrelationships of grapevine (Vitis vinifera L.) morphology in different phenological phases of BBCH[3]-scale measured evolutionary growth.

Keywords: plant morphology, grapevine, SysML

We created models in SysML linking the complexity of the plant world already abundantly illustrated and explained in botanical publications with a general-purpose graphical modeling language, used in system engineering, and supporting the specification; analysis; design; verification and validation of not only a broad range of systems applications, but also systems-of-systems.

Notwithstanding the existing disconnection between the two, their focus was to ask:

- What could SysML modelling principles offer when applied to plant biology?
- If SysML models could help biologists to understand how to integrate new methodologies complimentary with existing approaches?
- How biological-plants might now look when modelled in SysML?

We applied a general-purpose graphical modeling language tool Enterprise Architect SysML Edition, from Sparx Systems – with the aim of not only modeling the complex subsystems found within grapevine; but also and more broadly, to represent the morphological diversity of plants as a whole; so as to be able to reveal, from functional component parts, hidden internal structures and interrelationships.

This morphological diversity can hide the structural relationship between the functional components of plants: this is the reason why the SysML, as modeling language has been selected.

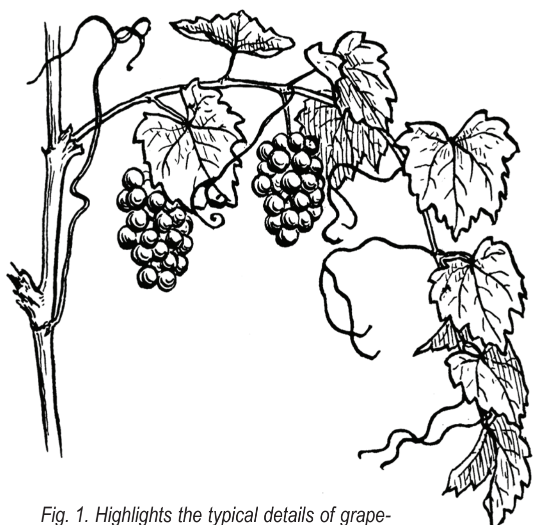

Fig. 1. Highlights the typical details of grapevine at BBCH 89 stage: berries; cluster size; and leaf age etc.

1 Department of Advanced Systems Development, QuantisLabs Ltd. Budapest, H-1118 Szamado u. 19/7. || Corresponding author's eMail: edit@hlaszny.eu

2 The SysML is a general-purpose modeling language for systems engineering applications. It supports the specification, analysis, design, verification and validation of a broad range of systems

3 The BBCH-scale is a scale used to identify the phenological development stages of a plant. The abbreviation of the scale is said to unofficially represent the four companies that initially sponsored its development; Bayer, BASF, Ciba-Geigy and Hoechst.

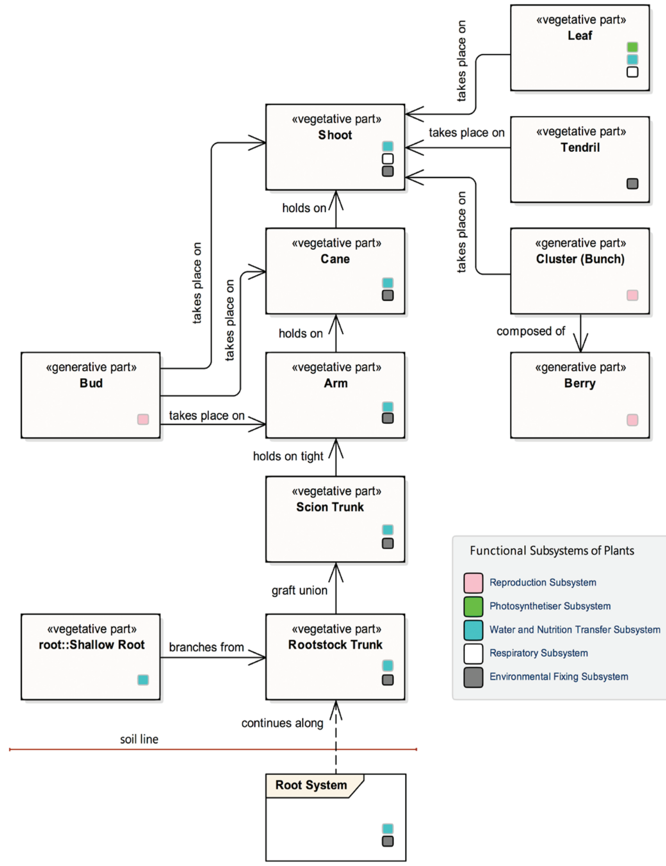

Fig. 2. By contrast, is a SysML Internal Block Diagram (IBD) showing the essential functional components/interrelationships of grapevine, at the same, BBCH 89 stage. The authors note the entities in SysML are singular in name (leaf, shoot, arm, etc.) as each block represents a generalized version of a singular object; and this is a standard practice in SysML modeling.

A SysML Internal Block Diagram can explain, by way of entity blocks, not only how an internal structure looks; but also how its constituent parts are interconnected. An IBD uses several diagram elements – such as blocks; ports; interconnections; and properties – to represent a multiplicity of connector paths; item flow directions; values; block properties and functions etc. There are numerous aspect which can be represented on an IBD, as multiplicity of a connector path, item flow direction, value or even functional role of block property.

The authors believe that the plants' subsystems can be listed as follows:

- Reproduction Subsystem,
- Photosynthetiser Subsystem,
- Water and Nutrition Transfer Subsystem,
- Respiratory Subsystem,
- Environmental Fixing Subsystem.

Each SysML diagram shows this coloured classification. It is of no coincidence that these five subsystems in plants are mirrored within the human anatomy:

- Musculatory System,
- Respiratory System,
- Alimentary System,
- Urinary and Genital Systems,
- Endocrine System,
- Nervous System,
- Cardiovascular System,
- Sense Organs.

As with plants, humans need similar functioning biological subsystems in order to live.

Compared with an innately static illustration, such as (Fig.1) for instance, a distinct advantage of SysML is it can depict time-dependent events as a 'sequence diagram' to show the interactions between structural elements – as for example in a sequence of sent and received messages; flow items; informational and/or material exchanges.

Without wanting to limit themselves to only models dependent on static time, the authors used three, or even four, SysML diagrams to characterize a specific plant issue. Incidentally, this use of multiple SysML diagrams is often found in engineering modelling applications too.

To illustrate the structural changes in grapevine the authors chose to use several different SysML diagrams to model the following BBCH growth values:

- BBCH 09 "**Bud burst**" green shoot tips are clearly visible (Fig. 3)
- BBCH 65 "**Full flowering**" 50% of flowers are open and first petals may have fallen (Fig. 4)
- BBCH 89 "**Fully ripe**" the fruit is fully-ripe in colour and abscission is visible (Fig. 2)

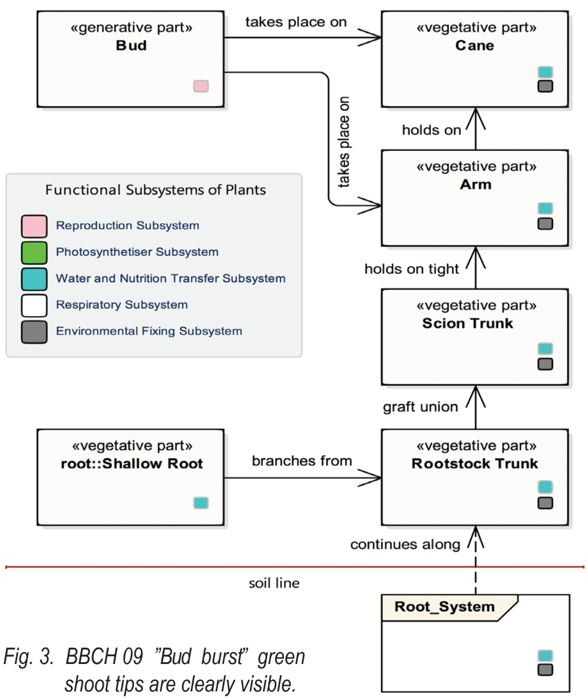

Fig. 3. BBCH 09 "Bud burst" green shoot tips are clearly visible.

The authors note the phenological development of grapevine is not only affected by varieties; but also by soil, weather conditions and plant health, which together, have a significant impact on both quality and yield.

The functional blocks in Figures 2-5 identify the following organic parts (listed in lexic–ographic order):

- **Arm** – and/or a 'branch', is more than one year old and attached to the trunk bearing canes and shoots; and develops en masse into the productive canopy.
- **Berry** – is found in bunches on the rachis, or stalk. Dependent on the crop type, mature berries have varied shape most often round and/or elongated; and variegated colour generally white; red; or blue and shades in between. The main parts of a berry are: skin (epidermis); berry flesh; and seeds.
- **Bud** – is the rounded undeveloped organ at the node of a cane and/or shoot, and is protected by overlapping scales. Two buds develop on the main shoots of grapevine at the leaf base: one is a summer/vegetative bud; while the other, a winter/dormant bud.
- **Cane** – is a one year old, mature woody shoot that forms the starting-point of the 'grafted' vine-stock its colour, thickness and cross-section being variety variants.
- **Flower** – is wind pollinated and found, in inconspicuous clusters, on the rachis of grapevine. There are three basic types: functionally male (androdynamic sterile); functionally female (ginodynamic fertile); and hermaphrodite (androdynamic fertile) flowers.
- **Inflorescence** – is a complex panicula type flower cluster on grapevine which when developed is hairless/bare and mostly green in colour. A medium sized inflorescence can contain 200 - 400 individual blooming flower buds/burgeons.
- **Leaf** – is the organ which breath and nourishes the grapevine shape; lobe size; and dentations change with each cultivar and the leaves grow at the hemispherical points of the stem shoots in acropetal sequence.
- **Root system** – in a vegetative propagated grapevine, has a root system with primary; secondary; tertiary; quaternary and further branching of the developed root in three zones of longitudinal segmentation.
- **Rootstock trunk** – is generally a short part of the trunk, above the soil line; and also under the graft union.
- **Scion trunk** – is the main stem/body of a vine stock between the root and stem system. It's vertical or skew in growth, and older stem parts can be both with/out branches.
- **Shallow Root** – is the root system which grows close to the soil line to catch precipitation on the ground surface. It consists of aerial roots which penetrate the soil surface during springtime; and if removed when the vineyard is ploughed, it can still quickly recover and regrow.
- **Shoot** – is the young, green and not yet woody stem on which leaves; flower clusters; and tendrils are developed at nodes. Not a regular cylindrical organ as its dorsiventrale structure is flattened into four types of sites.
- **Tendril** – is the climbing organ on a grapevine which coils for grasp around anything it touches, and after harvest it hardens and becomes woody. Tendrils and inflorescence are homologous in developing into flower clusters during ontogenezis.

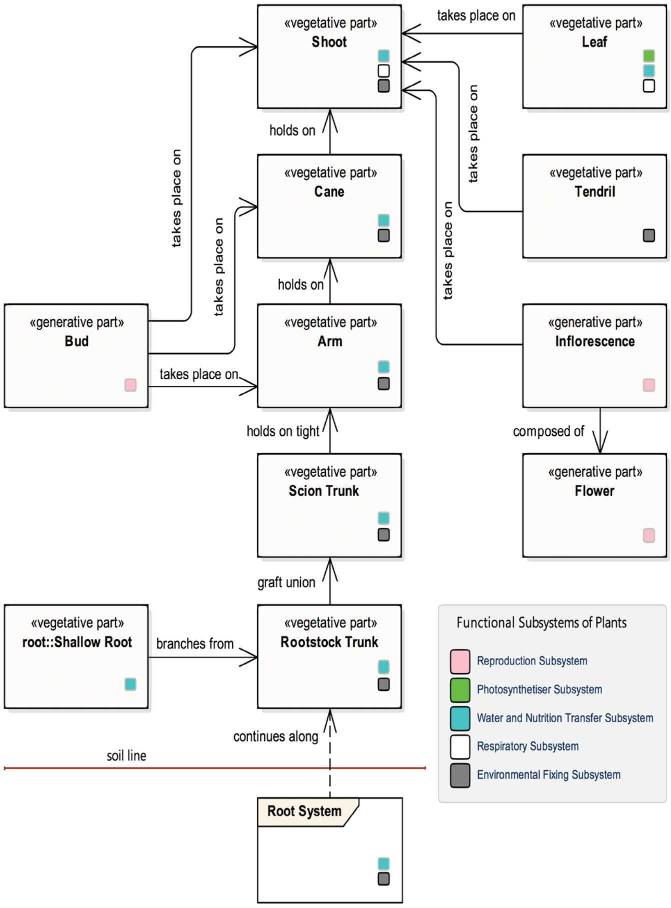

Fig. 4. BBCH 65 "Full flowering" 50% of flowers are open and first petals may have fallen.

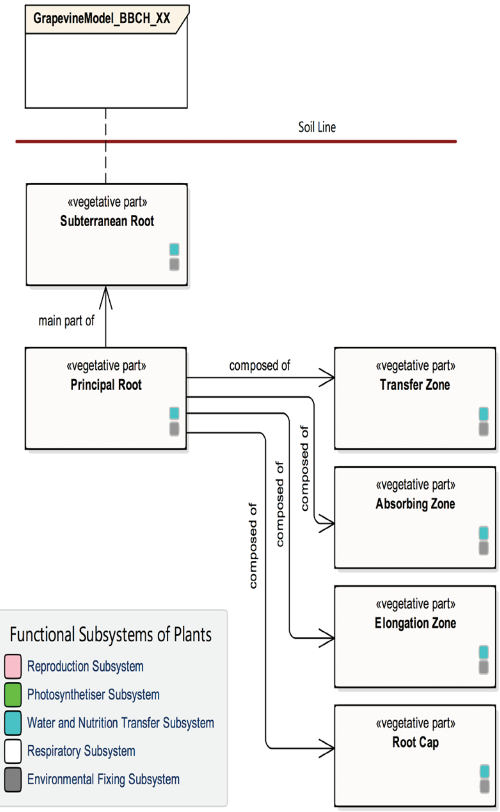

Fig. 5. Zoomed Root System. The structure of the Root Systems remains unchanged in different BBCH stages.

In the next column, Fig. 5 demonstrates how SysML models can be magnified to allow for complex systems to be modelled at multiple levels – each level denoting the immanent hierarchy of the system being modelled.

In Fig. 5 the functional blocks identify the following Root System parts:

- **Absorbing Zone** – a 1..3 cm long section behind the elongation zone, white in colour, the formation en masse of root hairs significantly increases the absorbent surface of the root system.
- **Elongation Zone** – a 2..5 mm long section behind the root cap.
- **Principal root** – the primary; secondary; tertiary; quaternary, etc. branches of the principal root. Roots have three zones that each terminate in a root cap.
- **Root cap** – young roots contain a root tip, a region of rapidly dividing cells protected by a root cap.
- **Rootstock** – the principal roots come from rootstock, which in vegetative propagated grapevine, is that part of the subterranean stem which is in the soil.
- **Transfer (condition) Zone** – the tertiary development of a root where root branches appear on the lower parts at a specific distance from the root tip.

This kind of modeling is being actively investigated using conceptual modeling languages such as SysML and OWL[4] and other Description Logic[5] languages, combining and discovering methods and solutions in a rapidly changing, highly diverse, ambiguous and unpredictable world.

Recommended Resources

1. Keller, Markus: The Science of Grapevines, Second Edition: Anatomy and Physiology 2nd Edition, ISBN-13: 978-0124199873, Academic Press, Elsevier Inc. 2015.
2. A. J. Winkler: General Viticulture. ISBN: 9780520025912, University of California Press, Berkeley, 1974.
3. G. L. Ceasy: Grapes (Crop Production Science in Horticulture), ISBN-13: 978-1845934019. CAB International 2009.
4. OMG Systems Modeling Language, V. 1.3, http://www.omg.org/spec/SysML/1.3/PDF
5. S. Friedenthal, A. Moore, R. Steiner: A Practical Guide to SysML, Morgan Kaufmann OMG Press, Elsevier Inc, 2008.

Budapest, 22 April 2017.

4 The Web Ontology Language (OWL) is a family of knowledge representation languages for authoring ontologies. Ontologies are a formal way to describe taxonomies and classification networks, essentially defining the structure of knowledge for various domains.

5 Description logics (DL) are a family of formal knowledge representation languages. It is of particular importance in providing a logical formalism for ontologies and the Semantic Web: the Web Ontology Language (OWL) and its profile is based also on DLs. A Description Logic (DL) models concepts, roles and individuals, and their relationships.