The `open-cbgm` Library:
Design and Demonstration

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9 December 2020

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Customizable, Standard-compliant Input

```xml
<listWit>
    <witness xml:id="A" />
    <witness xml:id="B" />
</listWit>
```

```xml
<app n="B00K0V0U0">
    <rdg n="a" wit="#A">ειπεν</rdg>
    <rdg n="b" wit="#B">ελεγεν</rdg>
    <note>
        <fs>
            <f name="connectivity">
                <numeric value="5" />
            </f>
        </fs>
        <graph type="directed">
            <node n="a" />
            <node n="b" />
            <arc from="a" to="b" />
        </graph>
    </note>
</app>
```
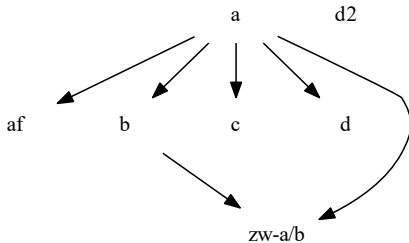
- Database is populated from a collation file in TEI XML format
- With a SQLite database, the entire process can be done locally

XML	Object	DB Table
witness	Witness	WITNESSES
app	Variant passage	VARIATION_ UNITS
rdg	Variant reading	READINGS
graph	Local stemma	READING_ RELATIONS

Local Stemmata

```xml
<graph type="directed">
    <node n="a" />
    <node n="af" />
    <node n="b" />
    <node n="c" />
    <node n="d" />
    <node n="d2" />
    <node n="zw-a/b" />
    <arc from="a" to="af" />
    <arc from="a" to="b" />
    <arc from="a" to="c" />
    <arc from="a" to="d" />
    <arc from="a" to="zw-a/b" />
    <arc from="b" to="zw-a/b" />
</graph>
```
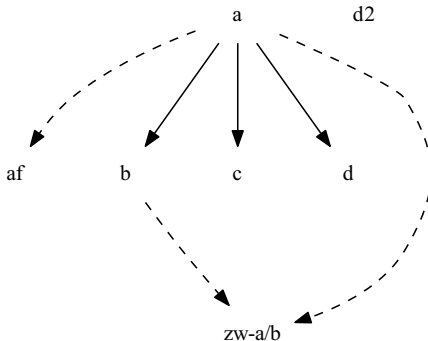
· Local stemmata are fully customizable in the XML input

Local Stemmata

- Reading types can be collapsed

```
-z defective -z ambiguous
```


3Jo 1:4/22-26

a: εν αληθεια περιπατουντα
af: εν αληθεια περιπατουντο
b: εν τη αληθεια περιπατουντα
c: περιπατουντα εν αληθεια
d: τη αληθεια περιπατουντα
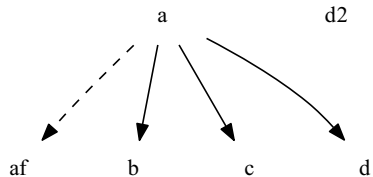zw-a/b: εν [13-15]τουντα

Local Stemmata

- Reading types can be dropped

```
-z defective -Z ambiguous
```


3Jo 1:4/22-26

a: εν αληθεια περιπατουντα
af: εν αληθεια περιπατουντο
b: εν τη αληθεια περιπατουντα
c: περιπατουντα εν αληθεια
d: τη αληθεια περιπατουντα

Local Stemmata

- Split attestations can be merged

```
-z defective -Z ambiguous --merge-splits
```


3Jo 1:4/22-26

a: εν αληθεια περιπατουντα
af: εν αληθεια περιπατουντο
b: εν τη αληθεια περιπατουντα
c: περιπατουντα εν αληθεια
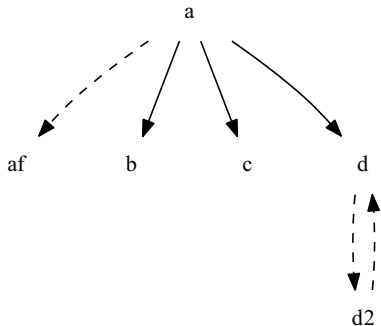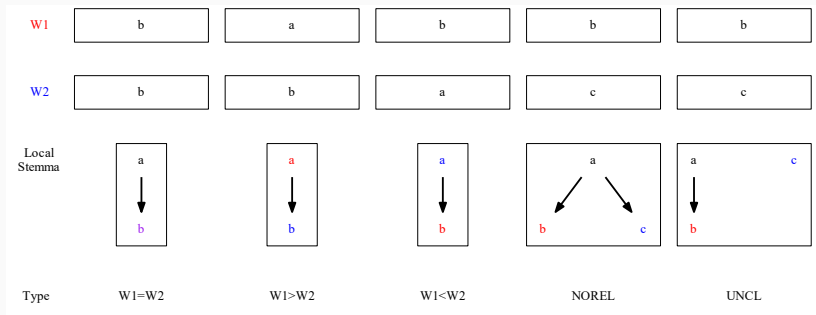d: τη αληθεια περιπατουντα

Genealogical Relationships

- The `open-cbgm` library encodes genealogical relationships relative to a given witness as bitmaps (one bit per passage)

$$agree = [1, 0, 0, 0, 0]$$
$$prior = [0, 1, 0, 0, 0]$$
$$posterior = [0, 0, 1, 0, 0]$$

$$norel = [0, 0, 0, 1, 0]$$
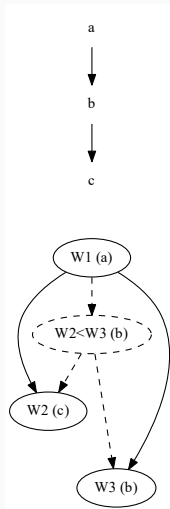$$uncl = [0, 0, 0, 0, 1]$$
$$expl = [1, 0, 1, 0, 0]^\star$$

# The `compare_witnesses` and `find_relatives` Modules

DEMO

Criteria for Explained Readings

- In the local stemma to the left, does *a* explain *c*?
- The "classic" rules of the CBGM as implemented by CCeH and Edmondson say *no*: the explaining reading must agree with or be directly prior to the explained reading
- Intermediary nodes may be needed to connect the global stemma

Criteria for Explained Readings
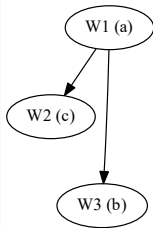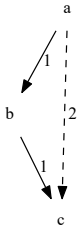
- The `open-cbgm` implementation relaxes this criterion: any reading with a path in the local stemma to the reading in question explains it
- No intermediary nodes needed (but multiple changes in the same passage may be implied along the edges)
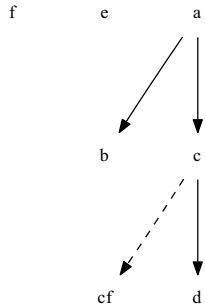
Genealogical Relationship Costs

- In "classic" rules, cost = 0 for agreement, 1 for disagreement
- "Agreement": same reading or readings connected only by dashed edges
- Uniform weight for all passages

```xml
<graph type="directed">
    <node n="a" />
    <node n="b" />
    <node n="c" />
    <node n="cf" />
    <node n="d" />
    <node n="e" />
    <node n="f" />
    <arc from="a" to="b" />
    <arc from="a" to="c" />
    <arc from="c" to="cf" />
    <arc from="c" to="d" />
</graph>
```


3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –

Genealogical Relationship Costs

```xml
<graph type="directed">
    <node n="a" />
    <node n="b" />
    <node n="c" />
    <node n="cf" />
    <node n="d" />
    <node n="e" />
    <node n="f" />
    <arc from="a" to="b">
        <label>2.079</label>
    </arc>
    <arc from="a" to="c">
        <label>4.159</label>
    </arc>
    <arc from="c" to="cf">
        <label>1.386</label>
    </arc>
    <arc from="c" to="d">
        <label>2.079</label>
    </arc>
</graph>
```
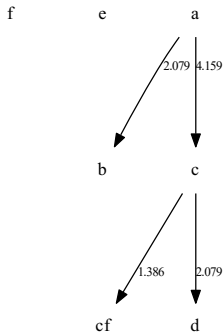
- In **open-cbgm**, cost = shortest path length
- Edge weights in `label` element
- e.g., scribal change log-likelihood $w = -\log p$

3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –

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Substemma Optimization

Ancestor	Explained	Cost
A	$[1, 1, 1, 1]$	3
B	$[1, 1, 0, 0]$	1
C	$[0, 1, 1, 1]$	1

- Substemma optimization can be cast as a *weighted set cover* problem
- Example: witness D, extant in four passages, has three potential ancestors A, B, and C
- The substemma {A} is *feasible*, in that it covers all of D's passages (i.e., explains D's readings at all of them)
- But {B, C} is feasible and *optimal* in terms of total cost (2 rather than 3)

Substemma Optimization
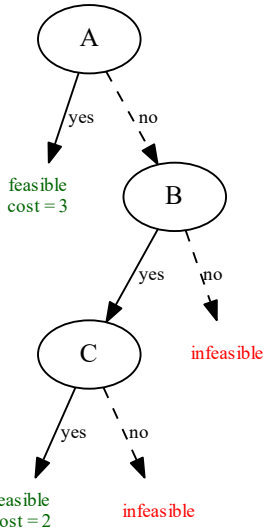
- For a witness with n potential ancestors, evaluating all of its 2^n possible substemmata by brute force would be prohibitive
- The *branch-and-bound* heuristic (pictured left) finds all minimum-cost substemmata quickly in practice
- Easily adpated to find all substemmata within a given cost

CBGM Iterative Workflow

DEMO

Conclusion

- The open-cbgm core library is freely available at
  https://github.com/jjmccollum/open-cbgm, and the standalone
  command-line utility is available at
  https://github.com/jjmccollum/open-cbgm-standalone
- A more user-friendly web interface is being co-developed with
  Tim and Jessie Stoel (Phoenix Seminary)
- Currently being used by David Flood (University of Edinburgh) for
  his PhD dissertation on GA 0150, 0151, 1506 and 2110

References

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Perathoner, Marcello. *cceh/ntg*. https://github.com/cceh/ntg.

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Appendix: Comparison of CBGM Implementations

	INTF/CCeH	Edmondson	open-cbgm
Input format	MySQL DB	Python script	TEI XML
Textual flow ancestry constrained by local stemma edges?	No	Yes	No
Lacunose witnesses allowed in textual flow?	Yes (CCeH)	No	Yes

Appendix: Comparison of CBGM Implementations

	INTF/CCeH	Edmondson	open-cbgm
Explanation only by same or parent reading?	Yes	Yes	No
Supports weighted input?	No	No	Yes
Genealogical cost function	Disagreement	Disagreement	Shortest path length
Intermediary nodes needed?	Yes	Yes	No