Generative Code Modeling with Graphs

Microsoft

Deep Program Understanding
https://aka.ms/MSRC-DPU

Marc Brockschmidt, Miltos Allamanis, Alexander L. Gaunt, Alex Polozov

Task

Code Generation

Background:

- **Grammar** of target language known (used by tree generation approaches)
- Code **semantics** can be represented **as graph**
- **Attribute grammars** describe flow of information in code parsing as graph

Key Ideas

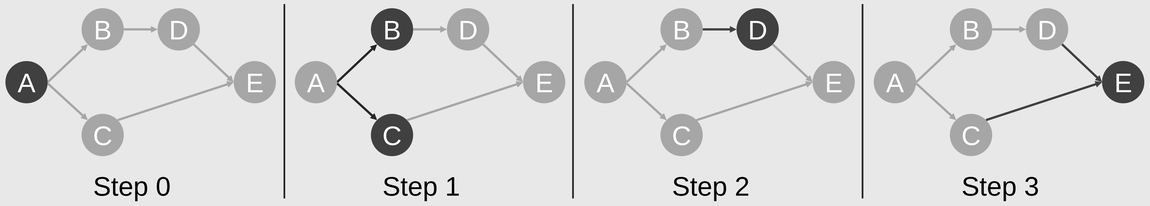
1. **Partially** generated **code** has **semantics**
2. **Neural Attribute Grammars** can learn semantics of partially processed code
3. **Asynchronous Graph Neural Networks** can propagate information in code generation order

Asynchronous Graph Neural Networks (Liao et al, 2018)

Observation: Most GNNs are synchronous, update all node states at each time step

Problem: Computationally expensive for large & almost-sequential graphs

Idea: Define schedule of information propagation steps:



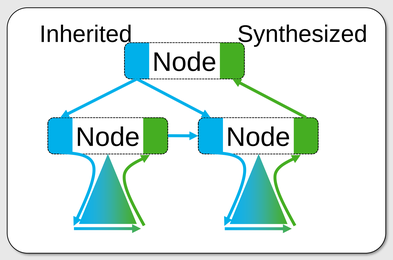
Graph Partition Neural Networks for Semi-Supervised Classification. R. Liao, M. Brockschmidt, D. Tarlow, A. Gaunt, R. Urtasun, R. Zemel (ICLR Workshop'18)

Attribute Grammars

Concept from the (program) parsing literature

Core ideas:

- Nodes in abstract syntax trees (ASTs) have attributes
- **Inherited attributes:** Information from parents and preceding subtrees
- **Synthesized attributes:** Information about subtree



Released Code

https://github.com/Microsoft/graph-based-code-modelling

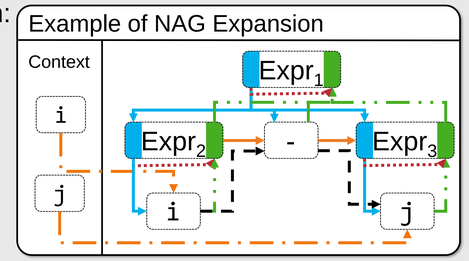
Included:

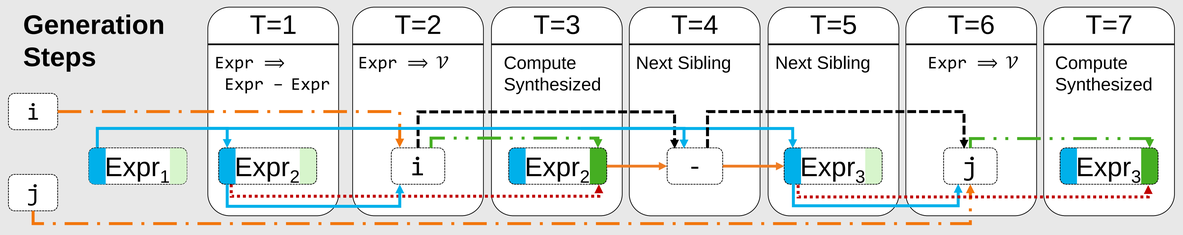
- Extracting program graphs & ASTs from C#
- Learning from programs with graphs (Allamanis et al, 2018)
- Code modeling with graphs in TensorFlow

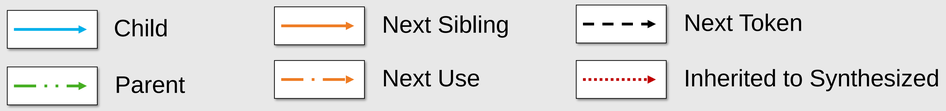
Code Generation with Neural Attribute Grammars

Neural Attribute Grammars use AGs to structure generation:

- Generate top-down, left-right
- Each node expanded using grammar rule
- Edges represent flow of information (neural attributes)
- Child, parent edges + semantic edges
- Message propagation only for currently generated node
- Connect to context information







Task & Evaluation

Code Generation in Context: Given a hole ■ in program fill it back in using just the context.

```
int methParamCount = 0;
if (paramCount > 0) {
    ...
}
if ( ■ ) {
        IParameterTypeInformation[] moduleParamArr =
            GetParamTypeInformations(Dummy.Signature,
                                     paramCount - methParamCount);
}
```

Qualitative Examples

```
public static String URItoPath(String uri) {
   if (System.Text.RegularExpressions
           .Regex.IsMatch(uri, "^file:\\\\[a-z,A-Z]:")) {
       return uri.Substring(6);
   }
   if (■) {            // Ground Truth: uri.StartsWith(@"file")
      return uri.Substring(5);
   }
   return uri;
}
```

G → NAG
- ■ uri.Contains(UNK_STR)
- ■ uri.StartsWith(UNK_STR)
- ■ uri.HasValue()

G → Syn
- ■ uri == UNK_STR
- ■ uri == ""
- ■ uri.StartsWith(UNK_STR)

```
startPos = index + 1;
int count = endPos - startPos + 1;
word = (count > 0) ? ■ : String.Empty;
            // Ground Truth: input.Substring(startPos, count)
```

G → NAG
- ■ input + startPos
- ■ input + count
- ■ input.Substring(startPos, endPos – count)

G → ASN
- ■ input.Trim()
- ■ input.ToLower()
- ■ input + UNK_STR

Within Projects

Model	PPL	Type-Correct (%)	Exact Match @1 (%)
Seq→Seq	87.4	32.4	21.8
Seq→NAG	6.8	53.2	17.7
G→Seq	93.3	40.9	27.1
G→ASN	2.6	78.7	45.7
G→Syn	2.7	84.9	50.5
G→NAG	**2.6**	**86.4**	**52.3**

New Projects

Model	PPL	Type-Correct (%)	Exact Match @1 (%)
Seq→Seq	130.4	23.4	10.8
Seq→NAG	8.4	40.4	8.4
G→Seq	28.4	36.3	17.2
G→ASN	3.0	74.7	32.4
G→Syn	**2.7**	**84.5**	36.1
G→NAG	3.1	**84.5**	**38.8**