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Sample Position

Term Indexing for the Beagle Theorem Prover

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The Beagle Theorem Prover

• Beagle is a First-Order-Logic resolution theorem prover with equality.

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The Beagle Theorem Prover

- Beagle is a First-Order-Logic resolution theorem prover with equality.
- Makes use of modular 'Background Theories' to make efficient use of known facts.

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The Beagle Theorem Prover

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The Beagle Theorem Prover

- Beagle is a First-Order-Logic resolution theorem prover with equality.
- Makes use of modular 'Background Theories' to make efficient use of known facts.
- This requires the carefully constructed 'Hierarchic Superposition with Weak Abstraction Calculus' in order to ensure consistency and completeness.

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The Beagle Theorem Prover

- Beagle is a First-Order-Logic resolution theorem prover with equality.
- Makes use of modular 'Background Theories' to make efficient use of known facts.
- This requires the carefully constructed 'Hierarchic Superposition with Weak Abstraction Calculus' in order to ensure consistency and completeness.
- Has been extended with term indexing to efficiently locate clauses which match the calculus resolution rules.

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Term Indexing Techniques

- Term indexers aim to collect all FOL terms which potentially match a 'query' term.
- Three important relations:

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Term Indexing Techniques

- Term indexers aim to collect all FOL terms which potentially match a 'query' term.
- Three important relations:

• 'Unifiable': $\sigma s = \sigma t$

• 'Instance Of': $s = \sigma t$

• 'Generalises': $\sigma s = t$

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Term Indexing Techniques

- Term indexers aim to collect all FOL terms which potentially match a 'query' term.
- Three important relations:

• 'Unifiable': $\sigma s = \sigma t$

• 'Instance Of': $s = \sigma t$

• 'Generalises': $\sigma s = t$

- Top-Symbol Hashing.
- Discriminant Trees.

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Fingerprint Indexing

• Maintain a collection of *fingerprints* for terms.

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Fingerprint Indexing

- Maintain a collection of *fingerprints* for terms.
- A term fingerprint is an array over $F \cup \{A, B, N\}$.

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Sample Position

Fingerprint Indexing

- Maintain a collection of *fingerprints* for terms.
- A term fingerprint is an array over $F \cup \{A, B, N\}$.

	Unification						
	f_1	f_2	A	В	N		
f_1	$ \mathbf{Y} $	Ν	Y	Y	N		
f_2	N	Y	Y	Y	N		
A	Y	Y	Y	Y	N		
В	Y	Y	Y	Y	Y		
N	N	Ν	Ν	Y	Y		

Matching							
	f_1	f_2	A	В	Ν		
f_1	Y	N	N	N	Ν		
f_2			Ν		Ν		
Α	Y	Y	Y	N	N		
В	Y	\mathbf{Y}	Y	Y	Y		
Ν	Ν	Ν	N	Ν	Y		

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Fingerprint Indexing

- Maintain a collection of *fingerprints* for terms.
- A term fingerprint is an array over $F \cup \{A, B, N\}$.

Unification						
	f_1	f_2	Α	В	N	
f_1	Y	Ν	Y	Y	N	
f_2	N	Y	Y	Y	N	
A	Y	Y	Y	Y	N	
В	Y	\mathbf{Y}	Y	Y	\mathbf{Y}	
N	N	N	Ν	Y	\mathbf{Y}	



Schulz, Stephan: Fingerprint Indexing for Paramodulation and Rewriting.
 In: Lecture Notes in Computer Science volume 7364 pp. 447–483 (2012).

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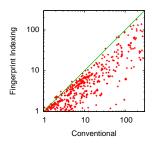
Indexing

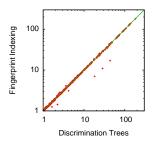
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Fingerprint Indexing - Potential Performance

Index	Run time	Sat time	PM time	PMI time	MGU time	BR time	BRI time
Noldx	16062.392	14078.300	8980.320	0.000	2545.080	2280.250	0.000
FP1	7006.758	6145.870	1816.100	25.710	450.760	379.570	40.150
FP6M	6000.177	5385.810	1181.710	38.240	99.110	39.010	55.660
NPDT	6082.246	5434.760	1184.750	64.910	83.110	33.200	79.910





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Base Fingerprint Indexing

 Beagle has been extended with a baseline implementation of Fingerprint Indexing.

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Base Fingerprint Indexing

- Beagle has been extended with a baseline implementation of Fingerprint Indexing.
- Required significant modification to current implementation (code refactoring and additional pointer structures).

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Base Fingerprint Indexing

- Beagle has been extended with a baseline implementation of Fingerprint Indexing.
- Required significant modification to current implementation (code refactoring and additional pointer structures).
- Operates on Beagle's most costly inference rule, superposition:

$$l \approx r \vee C \qquad s[u] \approx t \vee D$$
$$abstr((s[r] \approx t \vee C \vee D)\sigma)$$

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Current Indexing Results

• Still some issues causing excessive generation.

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Current Indexing Results

- Still some issues causing excessive generation.
- Speed results promising.

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Beagle Comparisons Sample Posit Fingerprint Indexing for the Hierarchic Superposition with Weak Abstraction Calculus

• As mentioned, current implementation is somewhat 'naïve'.

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Fingerprint Indexing for the Hierarchic Superposition with Weak Abstraction Calculus

- As mentioned, current implementation is somewhat 'naïve'.
- Fingerprint indexing could be greatly improved by tailoring it specifically to Beagle's FOL calculus.
- Main improvement is to consider Beagle's foreground and background terms.

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Fingerprint Indexing for the Hierarchic Superposition with Weak Abstraction Calculus

- As mentioned, current implementation is somewhat 'naïve'.
- Fingerprint indexing could be greatly improved by tailoring it specifically to Beagle's FOL calculus.
- Main improvement is to consider Beagle's foreground and background terms.
- Furthermore indexing may be applied to more of HSWA's inference rules; in particular simplification.

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Fingerprint Indexing for the Hierarchic Superposition with Weak Abstraction Calculus

- As mentioned, current implementation is somewhat 'naïve'.
- Fingerprint indexing could be greatly improved by tailoring it specifically to Beagle's FOL calculus.
- Main improvement is to consider Beagle's *foreground* and *background* terms.
- Furthermore indexing may be applied to more of HSWA's inference rules; in particular simplification.
- These extensions will not require so much modification; as the fingerprint indexing framework is already built.

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Other Potential Indexing Improvements

 An additional goal of the project is to consider how Fingerprint Indexing could be improved upon more generally.

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Other Potential Indexing Improvements

- An additional goal of the project is to consider how Fingerprint Indexing could be improved upon more generally.
- The main area to consider here is the sampling positions.
 Sampling many positions reduces the returned sets, but increases indexing overhead.

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Other Potential Indexing Improvements

- An additional goal of the project is to consider how Fingerprint Indexing could be improved upon more generally.
- The main area to consider here is the sampling positions.
 Sampling many positions reduces the returned sets, but increases indexing overhead.
- Large problems better suit indexing; but it is difficult to know ahead of time what a 'large' problem is.

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Metrics for Analysing Indexing Performance

• Speed - Not necessarily relevant

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Metrics for Analysing Indexing Performance

- Speed Not necessarily relevant
- False Positives Relevant, but can be misleading depending on number of positions being sampled.

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Metrics for Analysing Indexing Performance

- Speed Not necessarily relevant
- False Positives Relevant, but can be misleading depending on number of positions being sampled.
- Time Spent per Inference Booyah

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Comparing Varieties of Beagle

Un-indexed beagle.

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Comparing Varieties of Beagle

- Un-indexed beagle.
- Minimal Indexing.

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Comparing Varieties of Beagle

- Un-indexed beagle.
- Minimal Indexing.
- Full Indexing.

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Comparing Varieties of Beagle

- Un-indexed beagle.
- Minimal Indexing.
- Full Indexing.
- Indexing with Optimisations.

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Fingerprint Sampling Varieties

Reasoning. Cite shulz and FP/Speed balance

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Fingerprint Sampling Varieties

- Reasoning. Cite shulz and FP/Speed balance
- Different position samples

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