Evaluation of contact and distance prediction in CASP14

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Overview of targets and participants

38 evaluation units:
- 23 FM
- 15 FM/TBM

61 predictors:
- 39 contacts & distances
overview of submitted predictions (Jaccard distance = 1 - Intersection / Union)
Contact assessment

**Prediction format**

<table>
<thead>
<tr>
<th>i</th>
<th>j</th>
<th>p0</th>
</tr>
</thead>
</table>

- i and j are the indices of two amino acids
- p0 is the probability of the two residues being within 8 Å distance

**Evaluation:**

Prediction are trimmed to domains

- i-j pairs excluded if sequence space separation is < 6 aa
- Non-listed aa pairs are assigned p0 = 0

**Metrics**

- **Precision** = \( \frac{TP}{TP + FP} \)
- **Recall** = \( \frac{TP}{TP + FN} \)
- **F1** = \( 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall} \)
- **Entropy score** = \( 100 \cdot \frac{H_{struct,ext} - H_{struct,contact}}{H_{struct,ext}} \)
Results in contact prediction
Average precision - all groups all targets

Top 10 groups reached ~ 70% average precision (an excellent result)
Dependence on alignment depth

**average precision**

**best precision**
Best precision in CASP14 vs previous CASPs

Less reliant on deep alignments / better at extracting signal from small alignments
T1043-D1 - FM $\log(N_{eff} / \text{len}) = 0.01$

**Long L5 contacts**

Average precision $\approx 10\%$

Top performing precision $= 96.7\%$

Long L5 predictions Red = FP, Blue = TP
T1039-D1 - FM log(Neff / len) = 0.02

Long L5 contacts
Average precision < 20%
Top performing precision = 72.7%

Long L5 predictions Red = FP, Blue = TP
T1029-D1 - FM log(Neff / len) = 1.84

Long L5 contacts

Average precision 2.8% (sd =~ 4.2)

Top performing precision = 20%

Long L5 predictions Red = FP, Blue = TP
Ranking - $\text{sum}(\text{z-score} > 0)$

Metric: F-score

Head to head & paired t-test
**Ranking** - sum(z-score > 0)

**Metric:** F-score + 0.5* ESext

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<table>
<thead>
<tr>
<th>Method</th>
<th>G368</th>
<th>G010</th>
<th>G024</th>
<th>G488</th>
<th>G009</th>
<th>G125</th>
<th>G183</th>
<th>G351</th>
<th>G304</th>
<th>G198</th>
<th>G075</th>
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</thead>
<tbody>
<tr>
<td>tFold-CaT_human</td>
<td>0.433</td>
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<td>TripletRes - G010</td>
<td>0.341</td>
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<td>DeepPotential - G024</td>
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<tr>
<td>tFold-IDT_human</td>
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<td>0.392</td>
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<td>tFold_human - G009</td>
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<td>PreferredFold - G125</td>
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<td>PrayogRealDistance - G380</td>
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<td>0.047</td>
<td>0.024</td>
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<td>0.141</td>
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<td>0.001</td>
<td>0.004</td>
<td>0.030</td>
<td>0.017</td>
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<td>0.146</td>
<td>0.209</td>
<td>0.083</td>
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<td>0.311</td>
</tr>
</tbody>
</table>
Progress with respect to CASP10-13

- No difference in performance over top 10 groups
- Increased # of predictions at 50% precision
- Increased # of participants
CASP14 vs CASP13: Secondary structure content

Precision vs SS type - FL p > 0.5
Results in distance prediction
Distance assessment

**Prediction format**

List of contacts in 13 columns format:

- i j pN
- i and j are the indices of two the amino acids
- pN: C-beta distance within boundaries of the N-th bin: p1 (d ≤ 4), p2 (4 ≤ d ≤ 6), p3 (6 ≤ d ≤ 8) ..., p10 (d>20)

**Evaluation:**

Prediction are trimmed to domains
i-j pairs excluded if sequence space separation is < 6 aa
Non-listed aa pairs are assigned p10 = 1

**Metrics**

**Precision, Recall and F over each bin:**

- TP, FP and FN computed over binarised vector and Max(pN)

\[
\text{Mean Distance Difference} = 1 - \left( \frac{1}{10} \sum_{k=1}^{10} \frac{1}{N_k} \sum_{i=1}^{N_k} \frac{p_b(d_k) |D_k - d_k|}{D_{\text{max}}} \right)
\]

\[
\text{Mean Bin Neighbours} = \frac{1}{10} \sum_{k=1}^{10} \frac{1}{N_k} \sum_{b=1}^{N_k} \left( p_b(D_b) + \frac{p_b(d_{b-1}) + p_b(d_{b+1})}{2} \right)
\]
Graph-based metrics

**Strength**

\[ s_i = \sum_{j=1}^{N} a_{ij} w_{ij} \]

**Clustering Coefficient**

\[ c_i^w = \frac{1}{s_i(k_i - 1)} \sum_{j,h} \left( \frac{w_{ij} + w_{ih}}{2} \right) a_{ij} a_{ih} a_{jh} \]

**Average Shortest Path**

\[ sp_i = \frac{1}{N} \sum_{j=1}^{N} sp_j \]

\[ sp_{i\rightarrow j} = P(v_1, ..., v_i, ..., v_n) \mid P = \min_{i=1}^{n-1} \sum f(w_{i,i+1}) \]

**Diversity**

\[ D(i) = \frac{H(i)}{\log(k_i)} \]

*H(i) is the Shannon entropy*
Distance vs Contacts (average performance)

**Targets**

$R = 0.9, p = 5.3e-14$

**Groups**

$R = 0.96, p < 2.2e-16$
T1094-D2 - FM log(Neff / len) = 0.31
T1093-D1 - FM log(Neff / len) = 0.11

Distances map for target T1093-D1

Predicted (group 368, f1 = 0.329)

Helix-helix

Native

368

N-term helix-loop-helix Loop

cor = 0.88

cor = 0.40
T1029-D1 - FM log(Neff / len) = 1.84

cor = 71

cor = 73

238
T1080-D1 - FM/TBM

Distances map for target T1080-D1

Predicted (group 326, $f_1 = 0.272$)

Predicted (group 71, $f_1 = 0.148$)

Correlation: $\text{cor} = 0.81$

Correlation: $\text{cor} = 0.61$

Native

326
Errors in distance (Δ shortest path) vs errors in models (rmsd)
Performances
\( \text{sum}(z\text{-scores} > 0) \)
Correlation between metrics

Cumulative Z-score = \( z_{F1} + z_{\text{Bin} \_ \text{diff}} + z_{cc} + z_{sp} + z_{\text{div}} \)
Performance in distance prediction vs performance in TS

$R = 0.6, p = 7.1e^{-05}$
Conclusions

• Top 10 participants reached 70% average precision in contact prediction

• Apparent no progress in FM targets compared to CASP13 likely due to higher target difficulty and different content of secondary structure elements

• Both in contact and distance, very high quality predictions were made despite very low number of homologous sequences available

• Graph-based metrics might be helpful in interpreting/mapping distance predictions to local model quality

• Groups 488, 009, 368 (TFold_IDT_human, TFold_human, TFold_Cat_human) and 024, 010 (DeepPotenital, TripletRes) are consistently top ranking according to different metrics both in contact and distance predictions
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