Supplementary Information

Algorithm S1

RandomUpdateFunction

Require: Graph $G(V, A)$
for each $v \in V$ **do**
  let $u_1, u_2, \ldots, u_k$ genes regulating v in G
  let $l_1, l_2, \ldots, l_k, l$ the discretization level of $u_1, u_2, \ldots, u_k$ and v
  for each $x \in \{0, \ldots, l_1 - 1\} \times \{0, \ldots, l_2 - 1\} \times \cdots \times \{0, \ldots, l_k - 1\}$ **do**
    $F_v(x) \leftarrow \text{randint}(0, l - 1)$ ▷ a random integer between 0 and $l - 1$
  end for
end for
return $\{F_v | v \in V\}$

Algorithm S2

RandomGeneExpression

Require: Graph $G(V, A)$, update functions F_v, observed time step K
for each $v \in V$ **do**
  let the discretization level of v
  $v(0) \leftarrow \text{randint}(0, l - 1)$ ▷ a random integer between 0 and $l - 1$
end for
for $t = 1$ to K **do**
  for each $v \in V$ **do**
    let v: $u_1, u_2, \ldots, u_k$ genes regulating v in G
    $x = (u_1(t - 1), u_2(t - 1), \ldots, u_k(t - 1))$
    $v(t + 1) \leftarrow F_v(x)$
  end for
end for
return $\{v(t) | v \in V, t \in \{0, \ldots, K\}\}$

Detailed results of the performance on multi-level and Boolean discretization datasets

K	10	20	30	40	50	60	70	80	90
Ground truth networks, size = 50									
Precision	0.298 ±0.054	0.468 ±0.069	0.569 ±0.068	0.637 ±0.090	0.686 ±0.085	0.728 ±0.084	0.744 ±0.077	0.768 ±0.084	0.783 ±0.087
Recall	0.224 ±0.045	0.464 ±0.069	0.618 ±0.070	0.706 ±0.077	0.759 ±0.065	0.797 ±0.069	0.808 ±0.063	0.829 ±0.062	0.845 ±0.072
Structural	0.940 ±0.006	0.950 ±0.008	0.960 ±0.008	0.967 ±0.010	0.972 ±0.009	0.977 ±0.008	0.978 ±0.007	0.980 ±0.008	0.982 ±0.008
Dynamics	0.997 ±0.005	0.999 ±0.001	0.997 ±0.005	0.995 ±0.009	0.995 ±0.008	0.991 ±0.011	0.989 ±0.009	0.987 ±0.009	0.988 ±0.007
Synthetic networks, size = 50									
Precision	0.397 ±0.042	0.521 ±0.086	0.586 ±0.072	0.650 ±0.089	0.689 ±0.093	0.725 ±0.071	0.772 ±0.093	0.779 ±0.076	0.788 ±0.080
Recall	0.418 ±0.023	0.532 ±0.086	0.638 ±0.076	0.719 ±0.116	0.760 ±0.102	0.788 ±0.114	0.818 ±0.103	0.831 ±0.069	0.846 ±0.075
Structural	0.957 ±0.011	0.954 ±0.015	0.965 ±0.014	0.974 ±0.017	0.972 ±0.016	0.976 ±0.012	0.980 ±0.014	0.981 ±0.010	0.981 ±0.010
Dynamics	0.999 ±0.001	0.999 ±0.001	0.997 ±0.005	0.995 ±0.007	0.990 ±0.011	0.985 ±0.014	0.984 ±0.008	0.979 ±0.010	0.985 ±0.009
Ground truth networks, size = 100									
Precision	0.215 ±0.029	0.416 ±0.054	0.502 ±0.064	0.587 ±0.054	0.627 ±0.060	0.674 ±0.046	0.701 ±0.053	0.724 ±0.077	0.729 ±0.084
Recall	0.161 ±0.024	0.407 ±0.052	0.557 ±0.063	0.671 ±0.050	0.729 ±0.055	0.774 ±0.041	0.797 ±0.043	0.814 ±0.059	0.814 ±0.064
Structural	0.967 ±0.002	0.973 ±0.003	0.977 ±0.004	0.981 ±0.003	0.984 ±0.004	0.986 ±0.003	0.987 ±0.003	0.988 ±0.004	0.989 ±0.004
Dynamics	0.999 ±0.001	1.000 ±0.001	0.999 ±0.000	0.998 ±0.002	0.993 ±0.008	0.988 ±0.011	0.983 ±0.013	0.982 ±0.012	0.979 ±0.014
Synthetic networks, size = 100									
Precision	0.286 ±0.033	0.426 ±0.038	0.565 ±0.085	0.599 ±0.090	0.641 ±0.048	0.685 ±0.092	0.707 ±0.065	0.731 ±0.075	0.741 ±0.063
Recall	0.395 ±0.022	0.476 ±0.048	0.571 ±0.079	0.699 ±0.105	0.729 ±0.076	0.798 ±0.101	0.817 ±0.106	0.819 ±0.100	0.823 ±0.068
Structural	0.981 ±0.003	0.976 ±0.004	0.979 ±0.008	0.984 ±0.009	0.982 ±0.004	0.988 ±0.008	0.985 ±0.006	0.987 ±0.006	0.983 ±0.005
Dynamics	1.000 ±0.001	0.998 ±0.004	0.998 ±0.002	0.991 ±0.010	0.980 ±0.010	0.977 ±0.017	0.969 ±0.018	0.970 ±0.013	0.972 ±0.016

Table S1: Performance metrics (mean ± standard deviation) on multi-level discretization datasets across varying numbers of observed time steps K.

K	10	20	30	40	50	60	70	80	90
Ground truth networks, size = 50									
Precision	0.377 ±0.089	0.449 ±0.043	0.524 ±0.071	0.579 ±0.067	0.606 ±0.083	0.615 ±0.093	0.627 ±0.101	0.644 ±0.126	0.637 ±0.126
Recall	0.249 ±0.058	0.441 ±0.044	0.540 ±0.070	0.591 ±0.071	0.617 ±0.078	0.617 ±0.090	0.626 ±0.090	0.640 ±0.114	0.638 ±0.113
Structural	0.947 ±0.008	0.950 ±0.005	0.956 ±0.007	0.962 ±0.007	0.964 ±0.008	0.965 ±0.010	0.966 ±0.010	0.967 ±0.013	0.966 ±0.013
Dynamics	0.997 ±0.003	0.998 ±0.003	0.991 ±0.003	0.990 ±0.004	0.989 ±0.005	0.991 ±0.005	0.992 ±0.003	0.994 ±0.003	0.994 ±0.003
Synthetic networks, size = 50									
Precision	0.382 ±0.057	0.467 ±0.054	0.538 ±0.103	0.584 ±0.127	0.607 ±0.133	0.630 ±0.119	0.632 ±0.123	0.643 ±0.132	0.643 ±0.120
Recall	0.337 ±0.059	0.475 ±0.053	0.573 ±0.074	0.621 ±0.080	0.645 ±0.080	0.645 ±0.095	0.647 ±0.101	0.648 ±0.104	0.645 ±0.110
Structural	0.955 ±0.009	0.957 ±0.010	0.961 ±0.015	0.966 ±0.020	0.967 ±0.020	0.966 ±0.017	0.969 ±0.016	0.968 ±0.019	0.968 ±0.016
Dynamics	1.000 ±0.000	0.999 ±0.000	0.995 ±0.002	0.990 ±0.006	0.989 ±0.007	0.990 ±0.006	0.991 ±0.005	0.989 ±0.008	0.990 ±0.006
Ground truth networks, size = 100									
Precision	0.314 ±0.054	0.409 ±0.030	0.471 ±0.047	0.497 ±0.041	0.561 ±0.050	0.588 ±0.056	0.613 ±0.048	0.626 ±0.052	0.643 ±0.058
Recall	0.187 ±0.029	0.377 ±0.022	0.490 ±0.041	0.527 ±0.029	0.585 ±0.051	0.607 ±0.052	0.625 ±0.056	0.635 ±0.061	0.648 ±0.070
Structural	0.972 ±0.002	0.973 ±0.002	0.976 ±0.003	0.977 ±0.003	0.980 ±0.003	0.981 ±0.003	0.982 ±0.003	0.983 ±0.003	0.984 ±0.003
Dynamics	0.996 ±0.003	0.999 ±0.001	0.995 ±0.002	0.989 ±0.004	0.988 ±0.005	0.988 ±0.006	0.989 ±0.005	0.990 ±0.005	0.991 ±0.004
Synthetic networks, size = 100									
Precision	0.381 ±0.039	0.429 ±0.041	0.485 ±0.055	0.535 ±0.072	0.593 ±0.080	0.611 ±0.085	0.638 ±0.089	0.642 ±0.066	0.647 ±0.101
Recall	0.228 ±0.022	0.377 ±0.034	0.495 ±0.039	0.558 ±0.049	0.621 ±0.027	0.636 ±0.091	0.647 ±0.072	0.649 ±0.062	0.649 ±0.063
Structural	0.980 ±0.005	0.981 ±0.005	0.983 ±0.006	0.983 ±0.008	0.984 ±0.007	0.985 ±0.007	0.985 ±0.007	0.985 ±0.005	0.985 ±0.007
Dynamics	0.999 ±0.003	0.998 ±0.002	0.993 ±0.004	0.988 ±0.005	0.986 ±0.006	0.980 ±0.006	0.982 ±0.007	0.983 ±0.007	0.984 ±0.009

Table S2: Performance metrics (mean ± standard deviation) on Boolean datasets across varying numbers of observed time steps K.